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FUNDAMENTALS OF INCREASED PRODUCTIVITY

THE "Statement on the Economic Considerations Affecting Relations between Employers and Workers", which was issued as a White Paper in January (Cmd. 7018. H.M. Stationery Office. 2*d*. net), followed hard on a *Planning* broadsheet, "Men, Management and Machines", which hammered out the same imperative need for a higher output from each man and woman. Whereas, however, the White Paper gives no hint as to how this increase in productivity is to be secured, the broadsheet makes some concrete suggestions, and presses implications of the present man-power situation on which Lord Beveridge touched nearly three years ago in a chapter of his book, "Full Employment in a Free Society". The White Paper, in fact, derives its importance from the open admission by the Government, endorsed by both sides of the National Joint Advisory Council, of the extremely serious economic position of Great Britain. It is a clear and forcefully written statement of facts that neither the Government nor the trade unions have hitherto cared to admit.

The gist of the White Paper is easily summarized. Most of its arguments, in fact, have been pressed by every impartial commentator for the last eighteen months. We have for the last seven years "deliberately distorted and unbalanced our economic system, suffered the loss and permitted the depreciation of our capital resources, sold at least half of our external capital assets and gone into debt abroad. . . . This country is still running into debt abroad. Each month our balance of overseas payments is still unfavourable. Nevertheless, since the end of the war this country has proceeded rapidly to establish schemes of social improvements in the way of a housing programme and improved educational system, comprehensive old age, unemployment and health insurance systems and medical and other services". Moreover, the output of consumer goods from domestic industries is still inadequate, and until the output of British industry is considerably increased there is bound to be some fear of our ability to maintain the stability of prices and the orderliness within our industrial system which have characterized Great Britain throughout all the difficulties of the War.

The over-riding factor is the shortage of man-power. The fourteen industries specified, including coal-mining, all the textile industries, several metal-working, the clothing, footwear, furniture, paper and printing industries, needed in November 1946 a further 657,000 workers, or an increase of twenty-two per cent, to regain their total of mid-1939. There is no source from which all this additional labour can be drawn ; on the contrary, the impending raising of the school-leaving age will reduce the total labour force by 370,000 juveniles. Furthermore, while our total working population was about 20,324,000 in November 1946, or about 570,000 more than at mid-1939, this includes 4,985,000 in the Forces and Auxiliary Services, Government services, fire and police services, the professions, entertainment and

sport, leaving a balance of 241,000 smaller than in 1939; and the total is expected to fall to the pre-war level by 1948 owing to the fall in birth-rate and the further raising of the school-leaving age. Thus only an increase in output per head can provide an increased supply of goods from home industry and prevent a fall in the flow of imports as soon as the dollar loans are spent. The threat of inflation will remain while only £6,000 million of consumer goods and services face £7,000 million of incomes.

There is clear warning that without high production full employment itself is endangered, and that whether the standard of living can be improved depends on the output and efficiency of all our industries and essential services. The Government affirms its intention of maintaining control and ensuring that no unregulated increase occurs in the prices of essential goods and services; but it places fairly on the shoulders of both sides of industry the responsibility for steadying the costs of production, manning the essential industries and stepping up production until we have struck a balance between total demand and total supply.

In effect, the White Paper is an appeal, issued by the Government, and endorsed both by employers and by the trades unions. The *Planning* broadsheet shows a much clearer grasp of the magnitude and implications of the problem, and indicates some of the lines which Government policy must take, even at the cost of a break with past practice. It indicates rather more precisely the magnitude of our task in the production of capital goods and consumers' durable goods in quantities sufficient to meet arrears due to six years of war and replacements of material destroyed, including, for example, the provision of 750,000 new dwellings to meet immediate requirements, before starting on the extra three millions needed in the next ten or twelve years. Furthermore, the broadsheet directs attention to our commitments in Germany, where our joint responsibility in effect involves subsidizing for some time to come an additional population of about twenty-two millions.

On the labour force, *Planning* makes some pertinent comments. Our working population has increased since 1939 by about 3·3 per cent, solely in the number of women workers, and since the total population has increased by about the same proportion, the increase is not of itself likely to raise real income per head of population. Moreover, changes impending in our age-structure are likely to make for lower, rather than higher, total output. Hours of work are often shorter than before the War; and the increase in the number of paid workers not only necessitates, and may help to produce, an increase in output, but also increases the demand for labour in the transport, catering and entertainments industries.

On this question of deployment of the labour and mobility, *Planning* is much more realistic than the White Paper; and in the face of the arguments put forward it will be difficult to justify claims for shorter working hours as in the public interest. The corollary to the forty-hour week of an even greater increase in output per man-hour is driven home; and in view of some conflicting evidence it might be well worth while for some objective inquiry to be put in hand on that point, as was suggested by the Chief Inspector of Factories when he observed in his 1944 report that much research was still needed before the relation of output to hours of work was fully known, and that close scientific study of these and kindred problems would amply repay the time and effort involved. Even more realistically, the *Planning* broadsheet proceeds to inquire into actual performance and, to say the least, there is little evidence to be adduced that the productivity of industry has increased at all since before the War. Data in some industries are admittedly scanty; but the broadsheet states that in the coal, cotton, iron and steel and even the building industries, output per man-hour is appreciably lower than before the War.

The most valuable section of the broadsheet is the analysis of some of the causes which follows the discussion of performance. Except for coal-mining, where absenteeism may account for nearly half the drop in output per worker since 1939, the proportion said to be attributable to absenteeism and reduced physical effort is probably much less than half. Some of the causes may indeed well be temporary. Staleness, resentment at loss of high war-time earnings, lack of goods in the shops, housing and other family troubles precipitated by the end of the War, and taxation of wages under the 'pay-as-you-earn' system are obvious factors militating against regular attendance and maximum physical effort. Other causes of low productivity, which may also be temporary apart from those obvious difficulties of production planning, lay-out, training and re-tooling involved in re-conversion, may be seen in the shifting of the labour force, more than one third of which has changed jobs since the War, the acquisition of new peace-time skills, the poor condition of plant in many factories, and the difficulty under present conditions of planning production so that output is high and steady.

While, apparently, these are temporary factors which should gradually disappear, they are too interlocked to warrant excessive optimism; and some at least can be eliminated more by Government policy than by any other means. That is true of taxation and to some extent of raw materials and components, which are probably the greatest single cause of low productivity in manufacturing industry. The broadsheet quotes from a pointed article in the *Board of Trade Journal* of November 23, 1946, which shows that there is scarcely a major industry which is not, directly or indirectly, a consumer of raw materials listed as likely to be insufficient to meet demand during the next twelve months. The position is confirmed by the *Monthly Digest of Statistics* for November, and on top of all this there is the problem of fuel, the importance of which has recently been suddenly—and unnecessarily suddenly—brought home to everyone in the British Isles.

Taking a long view and ignoring short-term adjustments, industry itself could increase output per worker in three ways which are to some extent interdependent: by more regular attendance and

increased industry on the part of workers; by increased mechanization and more efficient machines and tools; and by better organisation and management. The first of these is essentially a question of improved morale, which usually will depend on a better understanding brought about by improvements in working conditions, involving the persuasion by the actions and attitude of management, rather than by official propaganda, that production is indeed a common task. It is here that contributions such as those of Dr. Mayo in his "The Social Problems of an Industrial Civilisation" are so important; for as *Planning* points out, concrete improvements in working conditions in themselves are not enough—and indeed amenities can be provided at too great a cost both in money and labour.

As *Planning* observes, the essence of management is getting people to do things, and for this it is necessary to understand people and to treat them properly. Special stress is laid in this broadsheet on two particular qualities: a sense of partnership with labour and a sense of service to the community; and, in referring to the value of joint consultation, the importance of giving the worker adequate information is stressed. That is endorsed by all the experience cited by Dr. Mayo, and the broadsheet once again emphasizes the vital responsibility of management in this field of human relations, and also that industrial management has its own contribution to make towards improving the relations between industry and Government.

Such considerations alone would emphasize the importance of the British Institute of Management, the composition of the Council of which has recently been announced. The association with this new enterprise of such men as Sir Clive Baillieu, Mr. C. G. Renold, Dr. J. E. Myers, Lieut.-Colonel L. Urwick, Sir Archibald McKinstry, Sir George Schuster and Mr. T. G. Rose gives every reason for confidence that the Institute will indeed raise the standard of management by helping to provide the right men with the right training and ideas. But as *Planning* pertinently observes, first-class recruits will not be found, nor will our present industrial leaders give of their best, while every manager is liable to indiscriminate political denigration—to be stigmatized by one side as a mercenary exploiter if he works for private enterprise, and by the other as an incompetent bureaucrat if he works in a nationalized industry.

Even from this brief survey, it is clear that there are several directions in which Government policy and action should and must reinforce the exhortations of the White Paper and whatever industry itself can do on either side. In the first place, it is primarily by Government action that the total labour force can be increased. The broadsheet refers to the importance of large-scale selective immigration, and powerful pleas have already been voiced for a deliberate policy of recruiting foreign workers for agriculture and for the mines. In particular, Prof. L. Robbins has argued convincingly for the use of an extra 100,000 such workers in the coal mines of Britain.

Nor is this the only way in which Government action could help. Taxation policy could be revised so as to invite the return of married women to industry, and intelligently administered pension schemes would encourage the able-bodied to continue at work even if only part-time. Taxation policy might also play a big part in increasing incentives to work; indeed, the desperate need for more production is sufficient reason for a critical review of the whole direct taxation system, and particularly that of 'pay-as-you-earn', from the point of view of incentives. Closely akin is the formulation of a consistent wage policy in which payment by results has an effective place, while finally the Government could, and should, overhaul the whole apparatus of economic control through one authority above the departmental level and competent to abolish those controls the usefulness of which is outweighed by the resources of time and labour they absorb, and to co-ordinate and simplify those that remain.

Such a review could undoubtedly make a direct contribution to the efficiency and pace of production, and would also be of value indirectly for its psychological effect on incentives. Equally, however, it is incumbent on the Government to review closely its whole use of man-power in the Services and to see that Great Britain's commitments are in keeping with her resources. That point was well raised in a House of Lords debate on January 29, which not only questioned whether we had the resources to maintain indefinitely a strong navy as well as a standing army of approaching a million, particularly in view of the declining numbers of young men reaching the age of eighteen each year, but also directed attention to the possibility of the Colonial territories supplying man-power necessary for overseas stations.

Both Prof. H. J. Laski and Lord Beveridge have pointed to the new functions which the trade unions and other professional organisations have to perform in conditions of full employment, and recent unofficial strikes emphasize the necessity for early and close attention to such matters as incentives, public relations, education and training, and the whole internal structure and organisation of the trade unions; this is necessary to enable the trade unions to make the great contribution which with wise leaders in close touch with the membership they undoubtedly could give to the well-being of a free society. As their defensive role diminishes in importance, so their constructive, positive contribution becomes potentially greater and more important. Prof. J. Jewkes has pointed out that acceptance of the policy of full employment will necessitate hard thinking by the trade unions regarding their future policy, and he suggests that such thinking might well start with a purely objective analysis of their past procedure. Indeed, if wage differentials are to be used to effect redistribution of labour, an examination of past practice is the basis for a decision as to the extent and speed at which such redistribution is possible.

No matter how wise and sound may be the Government policy and proposals for increasing productivity,

a high degree of courage and skill will be demanded of the Government in bringing the public to understand and accept measures which, in some quarters and at some times, are bound to be unpalatable. For this reason, the White Paper is a call to every unprejudiced citizen to help the creation of a sound and informed public opinion on the matter, and to see that criticism of Government policy is both fair and responsible. That is essential if fresh incentives are to be found and industrial discipline maintained in the new conditions of full employment by a further change in the status of the work-people and by their assumption of a larger share in industrial management. Full employment, as Lord Beveridge has pointed out, ultimately depends on how private citizens use their liberties.

THE BRONZE ART OF ANCIENT CHINA

A Descriptive and Illustrative Catalogue of Chinese Bronzes acquired during the Administration of John Ellerton Lodge

Compiled by the Staff of the Freer Gallery of Art. (Smithsonian Institution Publication 3805: Freer Gallery of Art Oriental Studies No. 3.) Pp. v+108+50 plates. (Washington, D.C.: Government Printing Office, 1946.)

IT is probable that anyone who came in contact with John Ellerton Lodge will be left with a strong impression of a man with a great sense of quality—quality of conception as well as of execution—as is suggested in the preface to the volume descriptive of Chinese bronzes add to the collection of the Freer Gallery during the twenty-two years that he was director, from its first year as a public institution until his death in 1942. This volume is designed as a memorial to the man and a record of his work; it contains a few notes from his hand, but these were not written for publication and are little more than memoranda. It is the collections themselves and in particular the fifty-six archaic Chinese bronzes here reproduced in large-scale photographs which are the true monument; but even they will be touched by a finer light for those who can recall Lodge and his appreciation. They will value the portrait included in this catalogue.

A brief introduction of four pages is prefixed to the volume by Mr. A. E. Wenley, surveying the present state of the study of Chinese bronzes and taking a cautious view of the position reached in interpreting the historical inscriptions as material for dating and also of the stylistic sequences proposed by such authorities as Karlgren and Jung Keng. While recognizing that the work done by these scholars in the classification of the decoration "is most important and contains much of the truth", he adds justly that our present knowledge of the subject is still inconclusive, and the bulk of the scientific archæological work is still to be done. He and his collaborator, J. A. Pope, have, therefore, only attempted a division of the Pre-Han Bronzes into Shang, Chou, and late Chou, and have regarded their task as "telling something about individual pieces"; but this, of course, does involve some general principles, though the self-denying method adopted prevents the authors from explaining what these are. What, for example, in the general quality and treatment of the Kuei on Plate XXVIII do they hold must strongly suggest a date later than Shang?

The notes given beneath the descriptions of the pieces are for the most part concerned with the inscriptions; but parallels for the decoration are sometimes adduced and declared to be characteristic of this or that period. This dry objective treatment is rather characteristic of the Chinese approach to the subject; but some of Lodge's own notes treat more of the structure and form of the vessels, as of Nos. 13 and 14, and show a confident sense of style as a criterion of period. But they are equally notable for their careful observation of significant detail. The long and important inscription on the covered vessel fang-i (Plates XXI and XXII) is discussed at some length by Mr. Wenley, with reference also to Sir Neil Malcolm's well-known inscribed Kuei and to Chinese controversialists; but the important fact about both vessels is that these inscriptions are generally agreed to refer them to the eleventh century B.C., early in the Chou Dynasty. They show a baroque profile, and it is noticeable that the vessels assigned by the authors to earlier dates show less relief. Though this fang-i does not bear the name Ch'en Ch'en included in the inscription, it is associated with a group which does, and is said to have formed part of a find of about thirty-five ritual vessels at Lo-yang in Honan. Mr. Wenley points out that if the whole group is to be assigned to the same period (which must be the eleventh century B.C.), then "a considerable change must be forthcoming in methods of dating on stylistic grounds alone"; for the variations are great. But this does not altogether vitiate a stylistic basis for the chronology of each type of vessel, which alone seems a scholarly line to follow. There is, however, much value in the remark made by Mr. Wenley, that geographical factors are likely to differentiate styles as well as the time element.

Several of the vessels here published are of very rare, or in our present knowledge unique, shapes, such as the Huo with cover in the form of a human face with bottle-shaped horns, and the pair of tigers said to have been found in Shensi, apparently some kind of incense burners. Heading the mirrors is an interesting late Chou example with bird decoration from J. H. Cox's excavations at Ch'ang-sha in Hunan. The type is recognized as of Shou-chow, and though this is almost four hundred miles away, Mr. Pope points out that both places were within the confines of the great 'extra-China' State of Ch'u in the third century B.C. Another very interesting mirror, Plate XXXVII, is extensively inlaid with a gold and silver design of entwined dragons, characteristic of the Warring States period. The technical difficulty involved in this kind of decoration on a mirror has been overcome by setting the true mirror of speculum metal in a case of ordinary bronze. Various types of inscribed Han mirrors are represented by examples in remarkable preservation, the rarest being No. 39.38, which is decorated with alternate masks of dragons and tigers, and dated A.D. 174.

The ritual weapons illustrated are a remarkable group, there being no less than five inlaid with turquoise, and of these three have jade blades. The ceremonial 'Sickle' is the most extraordinary of all. It measures nearly 14 in. in length and may well originally have had a wooden handle inserted between the butt and the haft. The position of the blade

seems scarcely to justify the name assigned to it, and it seems better to regard it as an example of ritual Ko similar to a number of others of which the jade blades only have survived, though admittedly not exactly of the form here found. Eleven of the weapons illustrated come from a group of twelve acquired with a romantic story of their discovery at Hsun-hsien, Honan, in 1931. Whatever the truth of the story, the fact remains that one here reproduced on Plate XLVII is inscribed with the name Marquis K'ang, which may well be the same name as that occurring on General Malcolm's Kuei which, as noted above, can be assigned to the eleventh century B.C. A feature of these weapons is the presence on three of them of figures or heads of monsters which in two cases are engulfing human figures. This would connect them with the well-known pair of bronze vessels with a similar motif in the round which were exhibited together at Burlington House in 1935–36. Its true significance has still to be explained.

The volume contains a bibliography of ninety-four publications, mainly recent, several of which do not seem to have yet reached Great Britain. It provides just the material which is required at the present stage of the study of archaic Chinese bronzes, and the authors can feel that it will stand the test of time and so be a lasting memorial to J. E. Lodge. It is to be hoped that it may be followed by similar volumes dealing with the other principal acquisitions which he made in the Departments of Persian and Chinese Painting, and Indian and Chinese Sculpture, including jade, of the Freer Galleries. They should be sure of a warm welcome not only from scholars, but also from all lovers of the art of the East, of which Lodge was such a discriminating judge.

BASIL GRAY

A MERRILL FESTSCHRIFT

Merrilleana

A Selection from the General Writings of Prof. Elmer Drew Merrill. (Chronica Botanica, Vol. 10, No. 3–4.) Pp. 127+394. (Waltham, Mass.: Chronica Botanica Co.; London: Wm. Dawson and Sons, Ltd., 1946.) 4 dollars.

DR. E. D. MERRILL was born at East Auburn, a suburb in Auburn, Maine, on October 15, 1876. In the seventy years of his life he has made such contributions to the study of botany that the editor of *Chronica Botanica* records his being introduced, to Swedish botanists visiting Harvard, as the American Linnæus. His first botanical paper appeared in 1899, and the mere list of his publications (the vast majority strictly botanical, and including some still in the press) occupies thirteen and a half octavo pages.

The present work is a happy gesture of friendship to Dr. Merrill in the year of his seventieth birthday and of his retirement from the directorship of the Arnold Arboretum. In addition to a chronological list of important events in his life and another of his publications, there is reprinted a selection from the more generally interesting of his works, mainly on taxonomy, phytogeography, and economic botany.

Merrill's main researches have been connected with the flora of Malaysia and especially with that of the Philippines. His earliest botanical papers dealt with North American plants. With his appointment in 1902 as botanist to the Bureau of Agriculture and Forestry, Manila, began his connexion with the flora of the Philippine Islands. Among many other activities, he initiated the herbarium of the Bureau of Science, Manila, the first specimens being those collected by him in 1902. Twenty years later the herbarium contained 275,000 mounted specimens. It is one of the tragedies of the Second World War that this fine collection was entirely destroyed in 1945 during the re-occupation of Manila in the final phases of the Japanese defeat. All taxonomists must sympathize with Dr. Merrill in his feelings of personal loss. It is no doubt some consolation to him, and to taxonomists generally, that thanks to his methods, and to his generosity, so much material was collected for duplicate sets which were distributed to other botanical institutions. Typification and the settling of other botanical problems necessitating re-examination of specimens is thus going to be a much easier task than it might otherwise have been. In this, as in other respects, taxonomists might well follow Dr. Merrill's example.

On the whole, a judicious selection has been made of papers, or extracts, for reprinting. One misses an example of Merrill's more strictly taxonomic work and would have welcomed at least one paper to illustrate his precise, lucid and well-balanced style in preparing descriptions. Of the twenty-three reprints, those likely to be of widest interest are the ones connected with the plant geography of Malaysia and with the distribution of economic plants. It is obvious in reading or re-reading these contributions how Merrill avoids accepting any hypothesis, more or less newly put forward, as an explanation of all problems connected with the distribution of plants. Again and again he shows his caution by reminding his readers how incomplete is our knowledge of the flora and vegetation of these wide-flung tropical lands. In dealing with cultivated plants he adversely criticizes the extreme diffusionist hypothesis that civilization, and with it all important methods in agriculture and many crop plants, arose only once, and then in the Nile Valley. He is strongly against any belief in such supposed lost continental lands as Atlantis and Mu, and his arguments that all such conceptions should be subjected to the acid test of biological facts are typical of his well-reasoned outlook on major problems of plant history.

W. B. TURRILL

EXPERIMENTAL PHYSICS

Analytical Experimental Physics

By Prof. Harvey Brace Lemon and Assoc. Prof. Michael Ference, Jr. Revised edition. Pp. xvi+588. (Chicago: University of Chicago Press; London: Cambridge University Press, 1946.) 33*s*.

IN revising their work for its second edition, Profs. Lemon and Ference have added some eighteen pages of new material, including many of the more recent developments in electronics and nuclear physics. The betatron, the cavity magnetron, the general principles of radar, and nuclear fission, are among the new topics mentioned. The treatment of the triode has been expanded, though the only hint as to its rectifying action is contained in an artist's design at the head of Chapter 33, which looks like one of the relevant graphs.

It is stated that the first edition of the book was selected as one of the sixty best-designed text-books of 1943 by the American Institute of Graphic Arts.

It must be unusual to find a physics book appraised by this standard, but it is an unusually well-illustrated book. Sequences of photographs are used to follow the progress of demonstration experiments; these contain in themselves material for detailed study and some interesting work with pencil and paper. Only one sequence fails to deliver its message; plate 54 shows a series of cinematograph frames of progressive waves, numbered at irregular intervals, and when the key to the arrangement has been found it appears that the period of the waves is twice that stated in the captions.

The general excellence of the book was commended in these columns when it first appeared, and the upper limit of its possible usefulness to university students in Great Britain was then considered. The present reviewer, thinking of its adaptability for use in schools, finds that some two-thirds of the work covers the ground of the usual advanced courses in secondary schools, and that the remainder, while beyond this standard, is presented so clearly that a good pupil interested in reading beyond the limits of his syllabus could readily follow it. Some parts of the 'syllabus' work are done in less detail than is customary in Britain, but this is amply compensated by the full and careful treatment of experimental dynamics, physical optics, and wave motion. It can be recommended as a valuable addition to the school science library, and the paper and binding are such as to stand up to the constant hard use it would sustain in this capacity. G. R. NOAKES

PIEZOELECTRICITY

Piezoelectricity

An Introduction to the Theory and Applications of Electromechanical Phenomena in Crystals. By Prof. Walter Guyton Cady. (International Series in Pure and Applied Physics.) Pp. xxiii+806. (New York and London: McGraw-Hill Book Co., Inc., 1946.) 9 dollars.

THE production of electric charges on certain crystals by the application of pressure was discovered by the brothers Curie in 1880. Until the First World War the phenomena were of scientific interest only, but with the researches of Langevin and Rutherford the use of ultrasonic waves became important in warfare at sea. Between the two Wars piezoelectricity became of great importance to radio in the control of frequency. During the Second World War millions of piezoelectric crystals were made for use in communications both by radio and by telephone. Corresponding to this intense industrial activity there has been a great development of the theoretical aspects of the subject.

The present volume has appeared at the end of one of the periods of most rapid development of the subject of piezoelectricity, and it is written by one who has contributed personally in large measure to that development. In its 806 pages it gives a comprehensive, detailed and reliable account of the subject, and it is at the same time a reference work and a text-book. It is mainly theoretical in treatment; few descriptions of apparatus occur, and the practical details of measurement are scanty. A few electrical circuits are given, but in general only the main features of these are mentioned.

The first seven chapters are concerned with fundamental theory of crystal elasticity, including vibrations in crystals, and the dielectric properties of crystals. One important feature of these chapters is the explicit formulation of the various elastic and dielectric properties for plates and bars of any arbitrary orientation. For those who have occasion to work in this field, these detailed tables will be of great help. Chapters 8–12 deal with fundamental piezoelectric theory. This is one of the most valuable parts of the book, for it compares in a most lucid manner the various theories which have been advanced. Coming, as it does, just after the recent intensive study of the Rochelle salt group of crystals, this section of the book is most welcome, as it puts into proper perspective the relation between the piezoelectric properties of the Seignette-electric and the quartz-like groups of crystals. Chapters 13–18 discuss piezoelectric resonators—the theory, an outline of the methods of manufacture, the influences of air-gaps, electrodes and special cuts both for quartz and other crystals. Chapter 19 is devoted to the piezoelectric oscillator. The next 140 pages, Chapters 20–27, are concerned with the Seignette-electric crystals. The properties of Rochelle salt are exhaustively described on the basis of a critical survey of the literature. This is a most involved subject, largely because so much of the original work was done without a full appreciation of all the factors which affect the results, and the new reader will be grateful for this clear analysis. The last five chapters deal with certain applications of the phenomena of piezoelectricity, pyroelectricity, certain optical effects in crystals, a sketch of the atomic theory of piezoelectricity and a brief account of ferromagnetism designed to show its relation to the properties of the Seignette-electric crystals.

In the introductory chapter on crystallography there are a few points which might have been better expressed. On p. 15 a polar axis is defined as one "having at its two ends faces of different forms, with different numerical indices". This unqualified definition would not be accepted by crystallographers. Similarly, the statement "such vectorial effects as pyro- and piezoelectricity are found only with crystals having polar axes" is scarcely consistent with the piezoelectric character of class (222). It is also unfortunate that although the Hermann-Mauguin notation is mentioned in the introduction, it is not used in the text. Giving numbers to the crystal classes instead of the now accepted international symbols is a retrograde step. On p. 16 the statement "Two opposite vertices of a rhombohedron lie on the trigonal axis, thus forming a three-sided pyramid at each end of the crystal" will be confusing to the student who has been taught to distinguish between rhombohedra and pyramids as separate forms. On p. 34 the definition of a stereographic projection appears to exclude the possibility of points occurring outside the primitive circle. Crystallographers will also be surprised to learn on p. 36, "If the stereographic projection is desired for a face belonging to a hexagonal or trigonal crystal, for which the indices are given according to the Miller or the Bravais system, it is necessary first to calculate the relative intercepts of the face on the three orthogonal axes".

These relatively trivial criticisms would be inappropriate in reviewing such a great work were it not that a second edition will almost certainly be called for soon. In conclusion, it would be fair to say that this book does for the subject of piezoelectricity what Voigt's "Lehrbuch" did for the whole subject of crystal physics. W. A. WOOSTER

WHAT CHEMISTRY OWES TO X-RAYS*

By Dr. KATHLEEN LONSDALE, F.R.S.

In the nineteenth century, the table of atomic weights and the periodic classification of the elements were obtained by classical chemical methods. In the twentieth century, X-ray methods have added to these, atomic numbers and atomic radii. The twin sciences of X-ray spectroscopy and X-ray crystallography were founded in 1912 by the famous von Laue experiment. By measuring the X-ray spectra of all the known elements from aluminium to gold, Moseley, in 1913, was able to show that each element could be assigned a number (not always in the order of the known atomic weights) which was later identified with the charge on the nucleus in the Rutherford–Bohr atom, or the number of extra-nuclear electrons in the neutral atom. But while the ideas of integral nuclear charge and of the *K*, *L*, *M*, etc., orbits of electrons were primarily due to investigations of X-ray spectra, the study of X-ray scattering by the rare gases has shown that the Bohr orbital model is inadequate, and has demonstrated the superiority of the Sommerfeld wave-mechanical model of the atom, with its statistical electron-density distribution and its range of energy states. Atomic structure is fundamental to chemistry.

X-ray spectroscopy and X-ray scattering combined have also given by far the most accurate value to date of Avogadro's number, $6{\cdot}0228 \pm 0{\cdot}0011 \times 10^{23}$, obtained by equating the wave-length of X-rays as measured with a ruled grating and with a crystal of known density and structure.

X-ray spectroscopy has provided analytical chemistry with a tool of great sensitiveness for the identification of individual elements, since each element gives a spectrum almost (although not quite) independent of its state of aggregation or of chemical combination, but in any case quite distinguishable from that of other elements. As little as 10^{-6} gm. of uranium can be detected by its X-ray spectrum. This X-ray method has led to the discovery and identification of new elements; some, like hafnium and rhenium, now isolated and accepted; others, like the natural element 93 (isotope of neptunium), detected by Mlle. Cauchois and her colleagues in certain tantalites and monazites, but still awaiting confirmation by other methods. The development of sensitive curved-crystal focusing spectrographs has enormously increased the possibilities of X-ray spectroscopy, which is not used in Great Britain as much as it should be, either in science or in industry.

The chemical action of X-rays is small but not unimportant. It is almost entirely due to direct ionization and to the production of further ionization and activation through photo-electrons. This is the case, for example, in the photographic action of X-rays, in the production of very pure water through the decomposition of organic impurity by prolonged irradiation, and in the action of X-rays on living tissue.

But the greatest debt owed by chemistry to X-rays comes from the fact that by means of X-ray crystallography the study of the constitution of matter has been extended to the solid state. One of the most important properties of the solid state is cohesion. It is a remarkable thing, but so familiar that we have ceased to wonder at it, that if we lift one end of a poker, which is a conglomerate of crystals, the other end comes up too. Newton remarked that it was the business of the philosopher to explain this property, which is not found in ordinary liquids or in gases, though liquids have a non-directed cohesion. We think of these directed, permanent forces as physical, but they are surely chemical too, for they are an essential part of the composition of the solid substance and are related to the nature of the chemical bonds between the atoms. Since the atoms are continually vibrating, the chemical bond is not even a static one, but is a constantly changing balance of attractive and repulsive forces. Ordinary methods of chemistry cannot be applied to the solid state, since dissolving, melting or vaporizing a substance destroys its solid character, and may completely change the molecular configuration or the nature of the inter-atomic bonds. The first X-ray crystal analyses by W. L. and W. H. Bragg heralded a new era in structural chemistry, an era in which the importance of atomic radii was first realized, although even now insufficiently realized by most chemists. It soon also became apparent that the former classification of bonds as being ionic or homopolar was entirely inadequate. Metallic and van der Waals bonds are chemical bonds, and bonds of intermediate character also exist. Moreover, X-ray analysis has shown that for many purposes structural architecture is of foremost importance, and exact chemical constitution a secondary refinement. These points will be illustrated by examples, although it is not always possible to separate them.

Chemists had thought of compounds, such as sodium chloride, as being formed by the combination of atoms of different kinds, one of which had lost an electron, the other having gained it, and the two together forming an ionic molecule. They could prove that the ions Na^+ and Cl^- exist in solution, but could only conjecture that they also occurred as such in the solid state. X-ray methods proved it; but showed at the same time that no individual molecule exists. The Na^+ ion in solid sodium chloride is surrounded octahedrally by six Cl^-, to none of which does it stand in any unique relationship. In losing an electron, the sodium atom, so to speak, sheds a skin, and then proceeds to surround itself by as many neighbours of the opposite sign as it can conveniently attract, bearing in mind their relative sizes and the mutual repulsion of the surrounding anions. The number of anions a cation succeeds in holding (its co-ordination number) depends mainly upon the cation to anion *radius ratio*. If the radius ratio is greater than 0·73 (that is, $\sqrt{3}-1$), there will probably be eight-fold (cubic) co-ordination, as in caesium chloride (CsCl). If it is between 0·73 and 0·41 (that is, $\sqrt{2}-1$), there will be six-fold (octahedral) co-ordination, as in sodium chloride (NaCl) or magnesium oxide (MgO). If it is less than 0·41 there will be four-fold (tetrahedral) co-ordination, as in beryllium oxide (BeO). The same principle may be illustrated in AX_2 compounds by the series calcium fluoride (CaF_2), with an 8 : 4 co-ordination ratio; magnesium fluoride (MgF_2), 6 : 3, and beryllium fluoride (BeF_2), 4 : 2; with decreasing cation size. Finite complex ions, such as CO_3^{2-} and $PtCl_4^{2-}$ can of course exist, but they obey similar structural

* Summary of lectures delivered at the Royal Institution on December 5 and 12, 1946.

rules. The relative unimportance of valency is nowhere more strikingly illustrated than in the random structures, such as $LiFeO_2$, where Li^+ and Fe^{3+} randomly occupy the cation positions in a rock-salt type of structure; or in the spinels, which may be either of the type AB_2O_4 (where the valencies $A + 2B$ add up to 8), or of the type $B(A, B)O_4$, in which A and B metal ions of different valencies randomly occupy equivalent positions. The actual existence of some compounds is dependent upon this size factor; $NaPO_3$ and Na_3PO_4 can both exist because P^{5+} is big enough to hold four O^{2-} ions around it; but N^{5+} is not, and therefore although $NaNO_3$ exists, Na_3NO_4 does not. Solid solution of one salt in another with which it is not isomorphous, for example, $MgCl_2$ in LiCl, can sometimes take place with formation of a *defect* structure, a structure in which there are vacant places. Here there must be considerable local disturbance of valency conditions. The fact that (in spite of the Law of Definite Proportions!) FeS may contain up to 55·5 atomic per cent of sulphur atoms is also due to a defect of cations in the structure.

When atoms are joined together by covalent bonds, molecules do exist. In fact, they need not be finite, but may be infinite in one, two or three directions (for example, tellurium, antimony and diamond). Such infinite molecules were unknown before X-rays revealed them. The molecules are held together by van der Waals forces, or by hydrogen or hydroxyl bonds, or by a measure of polarization. Bonds of a kind intermediate between the extreme ionic and covalent types not only exist, but also are most common. In the silicates, for example, the Si—O bond has 50 per cent ionic character. The study of the silicates by W. L. Bragg and his colleagues has written a new chapter in chemical history; it has, as the president of the Royal Society said recently, "transformed a chemical riddle into a system of simple and elegant architecture". In cases such as aluminium fluoride (AlF_3) and silicon fluoride (SiF_4), where an abrupt change of melting-point has been taken to mean an abrupt change from ionic to covalent binding, what is really involved is a change from an infinite lattice (all similar bonds) to a lattice of finite molecules (with strong interatomic, but weak intermolecular, bonds), the change being governed entirely by considerations of size.

Definite intermetallic compounds exist, as well as solid solutions. Chemistry now has to cover the whole field of metals and alloys. Hume-Rothery has shown that structure type in many alloys depends not on valency or chemical formula, but on the ratio of the number of free electrons to the number of atoms. This rule may be only approximate, but there does seem to be a marked analogy between the structure of some metals and of some defect ionic-compounds. Sodium, for example, consists of a body-centred cubic arrangement of positive metal ions, with about an equal number of electrons, free or nearly free to move, giving high thermal and electrical conductivity. The α-form of silver iodide consists of a body-centred cubic arrangement of negative iodine ions, with an equal number of positive silver ions forming an interstitial liquid, and giving a high ionic conductivity. There seems no good reason why the bonds should be regarded as chemical in one structure and not in the other. Interstitial solid solutions of small atoms in metal structures (for example, hydrogen in zirconium, carbon in iron) are of great industrial importance. The difference between a mixture, a solid solution and a compound is easily observable by X-rays. Each element or compound gives its own X-ray patterns, by means of which it can be identified. (Note the difference between chemical analysis through X-ray spectroscopy, which identifies the elements in a substance; and X-ray crystallography, which identifies the substance itself by comparison with a set of standards.) A mixture gives the patterns of both constituents; a solid solution gives an intermediate pattern, from which the proportions of each constituent can be found with an accuracy of 1 or 2 per cent. A different type of chemical analysis was that in which, by measurement of the positions and intensities of the powder lines from long-chain ketones, Shearer in 1922 deduced the lengths of the chains and the positions of the ketonic oxygens.

In the field of organic chemistry, the size and shape of the molecule, the arrangement of atoms in it and the nature of the inter-atomic bonds have always been of particular interest to chemists. The diamond and graphite structures were among the first to be determined, but even now they are not fully understood. It is not certain whether there is a concentration or defect of electrons between neighbouring carbon atoms in diamond, and some X-ray reflexions from some diamonds are not accounted for. The usual graphite structure holds for about 80 per cent of all specimens, natural and artificial; but there are other ways in which the hexagonal layer molecules can be stacked together. Graphite-potassium 'alloys' can be formed by the holding of potassium atoms between the layers; another argument for regarding the van der Waals forces as essentially chemical in nature. X-rays can explain why charcoal can adsorb gases so easily as to act as a catalyst in bringing reacting gases together, and why its adsorption is much increased at low temperatures. The first property is a question of the increase of surface when graphite is in a colloidal state, the second is that of a reduction of atomic vibration which otherwise hinders the entry of foreign atoms. In graphite the valency bonds are intermediate between single and double bonds, having a bond order 4/3. The binding in the layer molecules may alternatively be described as metallic. Measurements of diamagnetic anisotropy confirm that the electron orbits in the layers have exceptionally large areas. The shape of the benzene nucleus and the nature of the aromatic bonds have also been determined unequivocally by X-ray methods, without the use of any assumptions. In fact X-ray analysis, and careful Fourier determinations of electron density contours in particular, have provided an immense amount of evidence for the theory of resonance, or mesomerism. In aromatic substances, such as coronene, and in conjugated systems, such as sorbic acid, the lengths of the C—C bonds have been related to the bond order; and improved methods of three-dimensional Fourier syntheses are enabling such measurements to be made in structures where atoms would not be properly resolved in an ordinary two-dimensional Fourier projection. In aliphatic long-chain compounds such as paraffins or fatty acids, the C—C bonds are similar to those in diamond, and the carbon atoms are arranged in a plane zigzag at nearly the tetrahedral angle; but investigation of the links of the chain in polythene (where the effect of end-groups can be neglected) has shown that besides a large thermal motion normal (but not parallel) to the chain-length, there is an actual sideways spreading of the electron

cloud; an effect which is confirmed by diamagnetic measurements. X-rays can therefore provide evidence of electron-cloud distortion in molecule formation, as well as giving a measure of thermal vibration in different directions for the various atoms in a molecule.

Another important chemical problem upon which X-ray methods have given much information is that of hydrogen- and hydroxyl-bond formation. Although X-ray analysis cannot in general locate hydrogen atoms, because of their low scattering power, hydrogen bonds can be detected because of their reduced length as compared with van der Waals bonds. The effect of replacing hydrogen by deuterium has been studied, and also the configuration of water of crystallization and adsorbed water. Water layers, held in position by residual forces, can increase the layer spacing of clays from 10 to 20 A., and some protein structures also contain considerable amounts of water. Such structures form special cases of compounds in which two different molecules crystallize together. Picryl iodide (tetragonal) and hexamethylbenzene (triclinic) crystallize together to form an orthorhombic, pseudo-hexagonal layer structure. The suggestion, by Fraenkel and Rudall, that insect cuticles consist of alternating monolayers of protein and polysaccharide, promises a wide field of investigation.

Many natural fibres give good and characteristic X-ray patterns, from which the size and shape of the fundamental unit of structure (a link in a high-polymer chain) can be determined, and also the size, shape and arrangement of the fibre crystallites, or micelles. Cellulose and alginic acid, linear proteins such as the fibroin of silk and the keratin of birds and reptiles have been studied. Although the X-ray patterns are comparatively poor, it is a very striking fact that stretched and unstretched wool, hair and horn on one hand give patterns which, as Astbury has pointed out, are almost identical with those of stretched and unstretched myosin on the other. In spite of their very different chemical constitution, their structural architecture is similar (compare NaCl, MgO and Li_2TiO_3; or many of the silicates). The visibly crystalline proteins, such as insulin and hæmoglobin, also show definite similarities of intramolecular structure. X-rays have shown that some of the globular proteins are just polypeptide chains folded in different ways, and that when unfolded (denatured) they form linear fibrous proteins of about the same density. An artificial wool prepared from ground-nuts was the outcome of chemical research based on such deductions from X-ray data. The peculiar mechanical properties of rubber, which resemble those of animal tissues, are a consequence of its molecular configuration, and the differences between rubber (*cis*-) and gutta-percha (*trans*-), both high polymers of isoprene, are being studied by X-ray methods.

Bernal has summed up the different stages in X-ray investigation of complex substances as being (1) identification; (2) measurement of molecular weight; (3) measurement of molecular symmetry; (4) measurement of molecular size and shape; (5) determination of position of substituent groups; (6) of each atom; (7) and of the electron density distribution throughout the solid. One may add also the changes in atomic and electronic configuration that take place with change of pressure, temperature and time. In the analysis and synthesis of a complicated substance such as penicillin, X-rays can be, and have been, invaluable in identifying and checking up on degradation products and on synthetically produced material. Exact measurements of molecular weight (density multiplied by volume of unit cell multiplied by Avogadro's number divided by number of molecules in unit cell) by X-ray methods have been used to correct wrong chemical formulæ and to determine amounts of water of crystallization. Molecular symmetry can distinguish, for example, between *cis*- and *trans*-isomers. The study of sterol derivatives by Bernal showed that the size and shape found by X-rays was quite inconsistent with the then accepted stereochemical formula, and led directly to the present formula which has been confirmed by both chemical and X-ray measurements. Bernal was also able to suggest, even without a complete analysis, just where substituent groups must go in order to explain the double-layer formation in many sterols, and the single layers that occur in the sex hormones.

In order to determine atomic positions completely, it is necessary first to have sufficient X-ray measurements, and then to interpret them. The interpretation is sometimes simplified either by putting a heavy atom into the molecule, or by comparing isomorphous compounds, in one of which there is a fairly heavy atom. The first method gave the structure of platinum phthalocyanine and of $Fe(CNCH_3)_4.Cl_2.3H_2O$ very directly. It was also successfully used in the X-ray analysis of the two cholesteryl iodide structures by Carlyle and Crowfoot, although these were much more difficult because the heavy iodine atoms were not in special positions. The analysis of the structure of penicillin (Crowfoot and Rogers-Low; Bunn and Turner-Jones; to be published) was achieved by comparing the two isomorphous potassium and rubidium salts with the related, but not isomorphous, sodium salt. It represents the technique of X-ray analysis used at its fullest power, both in regard to difficulty of experimental manipulation and of reasoned interpretation. In the case of complex chemical substances such as these, X-ray and chemical methods go hand in hand, each owing much to the other.

Finally, it is possible, by means of X-rays, to study the thermal vibrations of atoms and molecules, movements which are influenced by, and which throw light upon, the nature of the chemical bond. The partial breakdown of crystalline forces that occurs when atomic groups begin to rotate, or when statistical structures are formed in which groups, by assuming random orientations, simulate a higher symmetry than they actually possess, must correspond to very peculiar conditions in the chemical bond. There are also crystals which, although regular enough to give good X-ray diffraction, behave in many respects like liquids. A study of these may help to bridge the difficult gap between relatively simple chemical compounds and the complex substances that constitute living matter.

THE TOTAL SOLAR ECLIPSE OF MAY 20, 1947

By Prof. F. J. M. STRATTON, O.B.E.

THE first total eclipse of the sun after the conclusion of the recent World War will take place on May 20 next. The belt of totality passes from Santiago in Chile, where the sun will rise in eclipse, across the Argentine, with Cordoba close to the edge of the belt, Paraguay and Brazil, leaving South

America at Salvador; it then crosses the Atlantic without touching any islands, enters West Africa just south of Monrovia in Liberia, runs through the Ivory and Gold Coasts, Nigeria, the Cameroons, French Equatorial Africa, the Belgian Congo, Uganda and Kenya, passes just south of Nairobi, and leaves the East African coast just north of Mombasa, the sun setting in eclipse. The width of the track varies from about 80 miles at sunset and sunrise to about 110 miles in Brazil and West Africa.

The Atlantic coastal regions crossed by the belt of totality are both very cloudy, wet areas in May, and the best chances of success for astronomical observations would seem to be provided by the high lands of Brazil, which can be reached by rail and air, north and north-west of Rio de Janeiro. One British expedition, under the leadership of Dr. J. A. Carroll, is going to Araxa; the other members of the party are Dr. Alan Hunter and Dr. Alan Baxter. Their programme consists of observations of chromospheric line-widths by means of an echelon spectrograph, a study by means of an objective interferometer of possible motions in and of the corona, and an examination of the darkening towards the sun's limb in the infra-red. It is expected that a party consisting of Mr. Michie and Mr. Ivan Thomsen, sent by the New Zealand Government, will join the British party; also a party of Australian radio-physicists, who will carry out a radio-noise programme.

The possibility of securing observations from the air in the West African zone has been carefully considered; but in view of the type of aircraft available and the heavily cloudy conditions expected, it was felt that there was no chance of improving on the spectrographic results obtained from the air in Canada in 1945.

Not much information has yet been received of other expeditions. The Saltsjöbaden Observatory in Sweden is sending two parties under the general supervision of Dr. Öhman, one to Brazil and one to West Africa. The main object of the double expedition is geodetic, to gain information on the shape of the earth by comparing carefully timed observations at the two stations. But it may be taken for granted that Dr. Öhman's presence indicates that part of the programme will be connected with the problems of the polarization of the coronal light.

It may be assumed that the Cordoba Observatory will organise an expedition, but no details have yet been received. The National Geographic Society and the U.S. Army Air Force are sending a joint expedition to Bocayuva in the State of Minas Geraes, about 400 miles north of Rio de Janeiro. The altitude of the sun will be about 40°, the duration of totality 3 min. 50 sec. The programme comprises coronal photographs, including colour photographs, polarization of coronal light, spectra of the flash and corona; the temperature of the corona near the limb will be studied and the Einstein relativity effect will be looked for, though the field of stars is not favourable for this purpose. Changes in the ionosphere at successive contacts will be watched, and during the eclipse *radio-sondes* will be sent up and the Air Force will fly observation aeroplanes equipped with instruments. The most important instruments will be taken to South America by air. Dr. Lyman J. Briggs, recently director of the U.S. National Bureau of Standards and now chairman of the Research Committee of the National Geographic Society, will lead the party. Fifteen observers, including Dr. van Biesbroeck and Dr. Weaver, will form the eclipse party and will come from the U.S. Naval Research Laboratory, the National Bureau of Standards, Georgetown Observatory, Washington, Yerkes Observatory and Lick Observatory.

The eclipse will be invisible in Europe, save as a partial eclipse in the extreme south of Spain.

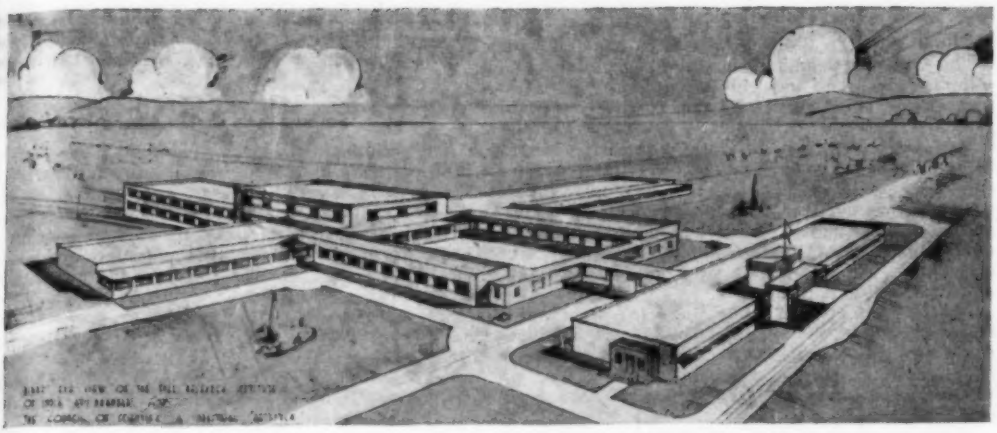
FUEL RESEARCH INSTITUTE OF INDIA

By Dr. J. W. WHITAKER
Director, Fuel Research Institute

THE Fuel Research Institute for India is being built in the Jharia Coalfield at Digwadih, some ten miles south of Dhanbad, and 170 miles north-west of Calcutta. The area of the site is 150 acres.

The work of the Institute will comprise technical investigations and research into the sampling, analysis and testing of fuels; combustion and furnaces; heat transference; coal carbonization; coal purification; briquetting; gasification; hydrocarbon synthesis and hydrogenation; tars and plastics; liquid fuels and internal combustion engine performance; smoke and atmospheric pollution. Fundamental research will not be neglected. Fuel technology, broadly speaking, is chemical engineering; it meets with the same problems in its field of action. Pure science is imperative: engineering technology is equally imperative, and economics must not be underrated.

India produces yearly about 25 million tons of coal valued at Rs. 30 crores at the pit-head. Her coal reserves have been estimated at some 65,000 million tons, but many seams are difficult to utilize economically. It is the main function of the Fuel Research Institute to ensure that this valuable supply of material be employed to the best advantage. At the same time, the properties and uses of all types of fuel will be studied, including petroleum, wood, charcoal, alcohol and gaseous fuels. There are, of course, a number of problems peculiar to Indian fuels. Thus in the coalfields of Bihar and Bengal, which are major coalfields, an important difference exists between Indian coals and those of Great Britain. In Britain most seams are relatively clean, or can be separated into clean and refuse bands. With Indian coals, however, the line of demarcation is seldom sharp. Frequently the clean coal has an ash content of 12–15 per cent or more—a feature attributable to the drift origin of the seams. These coals are difficult to purify by ordinary washing methods, a difficulty to be expected as the coal and foreign matter were originally deposited simultaneously as sediment from water. The coals in question are of the bituminous type, and many of the seams yield excellent coke with low sulphur content, in spite of the comparatively high content of ash. On the other hand, certain seams remain unworked because of still greater contamination with foreign matter. In other coalfields, for example, Assam, unusual difficulties are experienced because of abnormally high sulphur, present largely as organic sulphur and as sulphate. The ash content of these coals is low, the calorific value high; sulphur alone is the handicap.



ARCHITECT'S DRAWING OF THE FUEL RESEARCH INSTITUTE, INDIA

The problems of coal purification and processing are thus particularly important and require special attention.

Scope of Work

All departments of the Institute will co-operate in the conduct of schemes of research, but at the outset the following divisions are proposed: (1) Physical and Chemical Survey of coal resources (including field laboratories); (2) Carbonization and by-products (including colloids and rheology sections, tars and plastics); (3) Liquid Fuel Division (including hydrogenation, synthetic fuels, petroleum, alcohol, etc.); (4) Physics Division (including pyrometry, calorimetry, heat transference, X-ray and spectroscopy); (5) Gaseous Fuels Division (including combustion control); (6) Engineering Division (including preparation of coal for the market, boiler plant, etc.); (7) Library and Intelligence; (8) Administration and Office.

The present programme comprises a preliminary survey of the chief seams, including proximate and ultimate analyses, washability tests, ash analyses and tests, coking tests, carbonization assays, gasification tests, and investigations into tars. Subsequent work will include more detailed examination on the above lines and further researches into the utilization of the coals, either directly as fuels or indirectly as the products of carbonization, complete gasification, hydrogenation, and synthetic processes. Work will also be done on Indian oils and fuels not derived from coal, such as wood and alcohol. Pilot plant will be constructed as required.

Lay-out and Research Sections

It is expected that the construction and equipment of the laboratories and workshops will occupy two years. A third and fourth year will be devoted largely to the construction of plant. Broadly speaking, the lay-out is divisible into three main portions, namely, the administrative section, the laboratories and the technological block. Due to the climatic conditions, air-conditioning will be provided for the administrative and laboratory sections.

The General and Coal Survey Laboratories will include rooms for ash estimation, for ash fusion tests, and for research on refractories; inorganic chemical laboratories; rooms for high- and low-temperature assay, and coking and swelling tests; rooms for determination of moisture, volatile matter, carbon dioxide, etc., and for the ultimate analysis of coal; an inorganic analytical laboratory for determination of sulphur, phosphorus, arsenic, chlorine, etc.; calorimetry and balance rooms; preparation and solution rooms, and a small office.

For carbonization, by-products and liquid fuels the lay-out comprises a laboratory for special carbonization experiments; a routine laboratory for carbonization, blending and oxidation tests; an organic laboratory for work on liquid fuels; a physical chemistry laboratory for work on mineral oils and the like; preparation and balance rooms, and a small office.

In the Physical and Gas Research Subsections, rooms will be provided for X-ray control; pyrometer testing, ultra-violet and infra-red spectroscopy; gas analysis; combustion and gas research; a special gas research laboratory for fractionation of gases, thermal investigations, etc.; and a preparation room and office.

For special research, provision has been made for work in microscopy, coal petrography and related investigations; section-cutting and polishing; hydrogenation; rheological investigations and particle-size determination; research on colloidal fuels; electrical, magnetic and optical properties; chromatography and photo-chemical analysis; microanalysis, molecular research; hydrocarbon synthesis, and plastics research.

For coal preparation, equipment will be installed for making standard tests on the washability of coals. In addition, accommodation and apparatus will be provided for tests on commercial samples; and for special researches on methods of de-ashing of Indian coals, for example, by froth flotation. Rooms are also allocated for investigations into wetting and frothing and amalgamation agents with and without fine grinding, and for investigations into slurry problems in washeries, the stabilization and coal-cleaning media, etc. These laboratories will be near the technological block, within easy access of sampling, crushing and screening plants.

The Technological Block

The technological block will have the following facilities: (1) weighing, crushing, grinding, and sampling plant, and fine-grinding equipment; shatter test apparatus for coke; abrasion test apparatus for coke; screens; a room for the storage of samples for reference; (2) general stores; precision instrument shop; (3) general workshops; (4) room for electrical power distribution; (5) semi-technical carbonization ovens; (6) small gasification, hydrogenation and artificial oxidation plant; (7) boiler and pulverized fuel firing equipment; (8) vibrator screens for screen analysis on large-scale samples; and (9) small foundry.

Space is provided for boiler and other plant which may be required, for example, coke ovens, producer gas units, hydrogen generators, low-temperature carbonization plant, tar-hydrogenation plant, refineries, gas holders, Fischer–Tropsch units, and coal-washing plant.

A railway siding will be available for the technological block and the above plants in due course. Meanwhile, permission has been obtained to use the nearby railway siding of the Tata Iron and Steel Co.

Coal Survey Laboratories

To take stock of the basic supplies of fuel in India is but plain sense. Fuels provide the raw materials for heating and power generation and for numerous chemical industries, which in a planned economy require a degree of co-ordination. Fuels are essential to industries producing dyes, explosives, drugs, plastics, disinfectants and antiseptics; coal tars are of prime importance in highway construction; while in the manufacture of lime and cement, of bricks and refractories, of iron and steel, fuels are indispensable. Add to this that they provide usually the main source of power for all industries—generally through the medium of steam-raising plant—and their fundamental importance is unquestionable. Fuels, however, are a wasting or diminishing asset in contrast to water-power. Consequently reserves become of great significance. In India reserves of good coking coal are disconcertingly low, according to present statistics, reserves of iron ore of excellent quality being far in excess of the known available supplies of coal suitable for the manufacture of the requisite metallurgical coke. A policy of conservation for such coals may have to be adopted.

It is thus necessary at the outset to make a survey of the types of coal and the amounts available, and it is proposed to establish, as in Great Britain, coal survey laboratories in the major coalfields, staffed and equipped for the sampling and testing of fuels. Standard methods will be adopted wherever practicable. It is not the intention, however, to confine the functions of these laboratories to the assessment of resources, qualitative and quantitative. They will be encouraged to help in the numerous problems which arise in industry, whether fuel-producing or fuel-consuming. Moreover, should national policy so decide, these stations may also serve in the control of distribution and utilization of fuel. Meanwhile, their main function is the physical and chemical survey of the fuels available. Needless to say, in this work the Fuel Research Institute will co-operate closely with the Geological Survey and the Mines Department. The coal survey for the Jharia Coalfield will form part of the work of the Institute. The officers of the various survey stations will be trained at the Institute, and close liaison maintained between them and headquarters by such means as half-yearly conferences.

Staffing and Expenditure

The technical, administrative and artisan staff at the Institute will number between 100 and 200. The administrative staff will be of the order of 20–30; the technical staff will have 15–20 senior officers with 40–50 juniors, and an equal number of laboratory assistants and mechanics. Adequate unskilled labour has also been allowed for. Each of the field survey stations will carry a staff consisting of one or two senior officers, with 5–10 juniors, and a proportionate number of assistants for office and laboratory work. In some cases, unusually heavy charges have had to be anticipated for accommodation, transport, apparatus and chemicals, especially if the stations are remote from towns.

The annual expenditure of the Fuel Research Institute will be of the order of £100,000, excluding the expenditure on the field survey stations, which will vary with their number, but is expected to be of the order of £5,000 each. The capital cost of the central Institute and of the survey stations is of the same order as the annual expenditure, say £120,000 for the main Institute and £7,000 for a survey station.

The foundation stone of the Fuel Research Institute was laid by the Hon. Mr. C. H. Bhabha, Minister for Works, Mines and Power in the Interim National Government, on November 17, 1946.

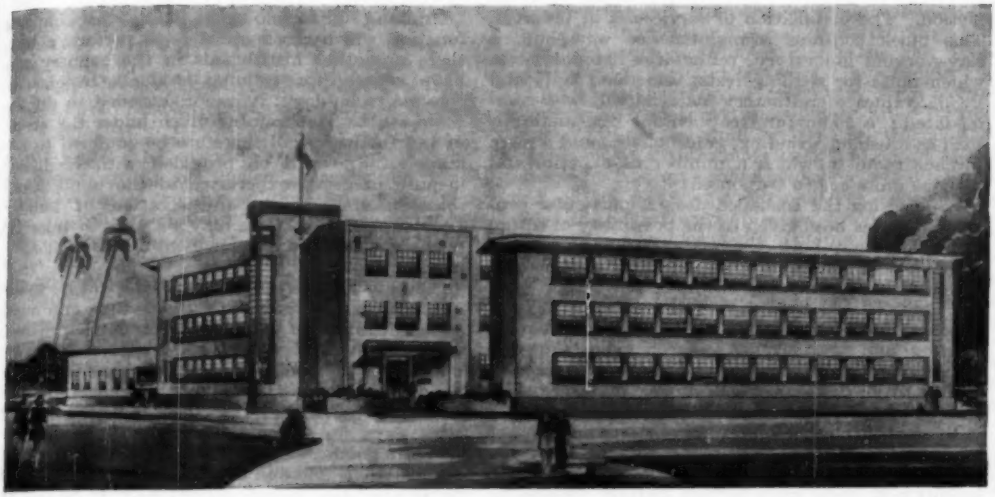
CENTRAL GLASS AND CERAMIC RESEARCH INSTITUTE, INDIA

By Y. P. VARSHNEY

Acting Officer-in-Charge, Central Glass and Ceramics Institute

THERE are few fields of industrial development in which scientific investigation has played, during the last twenty-five or thirty years, such a decisive part as in the glass and ceramic industries. Whereas in these industries spectacular developments have taken place in the industrially advanced countries of Europe and in America, conditions in India have remained comparatively static, although under the stress of war there has been some expansion.

Attention was directed to the unsatisfactory condition of the Indian glass industry and to the need for an Institute for training and research in glass technology by the Indian Industrial Commission so early as 1918, and this was further stressed in the report of the Indian Tariff Board on the glass industry in 1932. It was considered that the industry in India could not be expected to make satisfactory progress or make much headway without the aid of properly organised technological institutions, although the industry enjoys numerous advantages such as availability of raw materials, labour and a ready market within the country. The need for research was never felt so keenly both by the Government and the industry as during the War, when large and immediate supplies of glass and ceramic goods were required, and the Indian industry was hard put to meet the



Architect's drawing of the Central Glass and Ceramic Research Institute, India

demand in respect of quantity and quality, as well as of variety. It was to fulfil this urgent need and to create an organisation for helping the glass and ceramic industries in the application of scientific methods that the Government of India, through the Council of Scientific and Industrial Research, decided to establish the Central Glass and Ceramic Research Institute.

The preliminary details for its establishment were worked out by a committee under the chairmanship of Sir S. S. Bhatnagar. A report embodying its proposals was submitted by the committee to the governing body of the Council in August 1944, and on the basis of its recommendations the Council decided (*a*) that the Institute be located at Calcutta, which is an important centre of glass and ceramic industries in India, and which offers many other advantages for the work and growth of an institution of this nature, and (*b*) that a sum of twelve lacs of rupees be provided for the capital expenditure of the Institute.

Site and Buildings

The site selected for the Institute is in one of the southern suburbs of Calcutta in comparatively quiet and open surroundings. It measures approximately 650 ft. × 440 ft., the shorter side on the west giving the road frontage; it is nearly seven acres in area. The major part of this plot is expected to be taken up by the Institute buildings, but a small portion may be utilized for building residential quarters for some of the senior staff, if this is considered necessary at a later stage.

The buildings of the Institute have been designed in an L-shaped plan and will consist of two sections, namely, a main building which is ultimately intended to be a three-storeyed structure, although only two storeys may be built at present; and the technological block, which is single-storeyed and has, for the greater part, a north-light roof.

Such a division was considered desirable in order that laboratories for precision work, library, museum, offices, etc., could be located in the main building, while furnaces, workshop, machines for raw material treatment, etc., and large testing units, the operation of which is of necessity attended by considerable vibrations and noise, could be placed in the technological block. However, these two sections, though distinct, are to be close together and connected so as not to hamper in any way the progress of co-ordinated operations being simultaneously carried out in both of them.

The main building, with a floor area of about 17,500 sq. ft. on each floor, will form the shorter arm of the L-design about 230 ft. long facing the roadway, as also the first 145 ft. of the longer arm which extends to a total length of nearly 325 ft. The remaining 180 ft. length of the longer arm is occupied by the technological block, which has a covered floor area of about 16,000 sq. ft. The main entrance will be on the outside of the corner of the L, facing the roadway.

On the ground floor of the main building, three spacious museum rooms will form the major part of the frontage. By the side of these will be a drawing office and blue-print room; while facing them across a central corridor which runs the whole length of the L will be the physical and physico-chemical laboratories, in which spectroscopic, spectrophotometric, X-ray and other equipment for the study of physical properties will be housed. Other rooms on the same floor will include a room for optical testing and instruments, electrical laboratories, laboratory for enamelling and decorative work, a constant-temperature room and a dark room for photographic and spectrographic work. On the first floor, directly above the museum rooms, will be the conference room, library and the lecture hall; there will be sitting-rooms for officers above the main entrance. Facing the library and lecture hall across the corridor will be the chemical laboratories, and in the other wing on this floor there will be a room for petrographic and microscopic work, and also three rooms for office, records and statistics.

The construction of the technological block was started in September 1945 and is now nearing com-

pletion. The installation of services is in progress. This block contains a maintenance workshop, a clay-working laboratory, refractories laboratory in which units for spalling tests, underload tests and P.C.E. values of refractory material will be accommodated; a room for treatment of raw materials such as crushing, grinding, grading, etc., and a large furnace room in which a number of experimental furnace units are to be housed.

In choosing the L-shaped design, particular consideration has been given to the possibility of future expansion, and both the main building and the technological block are capable of considerable expansion independently without detracting from the architectural harmony of the entire structure. Besides, due attention has been given to adequate lighting and ventilation, ease of movement and communication inside the building, as well as suitability to local weather conditions. It is proposed that the main building shall be air-conditioned.

In view of the developments in fittings and devices used in laboratory services and of the great importance of such services in a laboratory, much attention is being given to this feature. Besides an adequate water supply, the Institute laboratories will have town gas supply, A.C. and D.C. electric supply and service lines for compressed air and vacuum according to requirements.

Functions

The functions of institutions concerned with technological subjects are objective in character, namely, the improvement and development of the particular industry or industries with which they are connected. This forms the chief objective of the Institute, and in keeping with it greater emphasis will be laid on industrial research and development of glass and ceramic processes. However, it is to be borne in mind that fundamental research has also to be promoted and encouraged, as without advancement in fundamental knowledge, no new industrial work of importance will be possible. Thus the Institute will aim at fundamental research having a bearing on different branches of glass and ceramics.

To attain its objective of helping the growth and development of the glass and ceramic industries, the Institute must engage in activities of a diverse character. In a country like India, where the number of technically trained persons engaged in industries is very small, and knowledge about many of the methods of manufacture followed nowadays abroad is either completely lacking or scanty, an institution which can give technical assistance to the industry can serve a very useful purpose. To give such technical assistance will, therefore, be one of the immediate functions of the Institute. This will be directed largely towards improvement of the existing technique of manufacture followed in Indian factories, as well as helping in the adoption of manufacturing processes which have so far not been undertaken in India. Such technical assistance is expected to be largely confined to the early stages, until the progress of these industries encourages the growth of independent consulting technologists and agencies; and as these grow, the Institute will curtail this aspect of its activities. To promote the above aim, the Institute will also undertake the collection of data and dissemination of information by means of publications, discussions, lectures and visits of technical personnel to industrial works.

Training of technologists is another important function which the Institute will perform; but as there are other institutions in the country which have courses for training students in glass and ceramic technology, it is not intended to duplicate their work. The training given under the auspices of the Institute will therefore be confined to a few students who will be provided with facilities to acquire practical experience in the application of scientific methods to the solution of industrial problems, so that they may be able to take independent charge of technological duties in glass and ceramic factories.

Another function of the Institute will be to serve as a central organisation for the testing, grading and standardization of glass and ceramic raw materials and finished articles. This will include calibration of appliances and control instruments. As yet, there is no organisation in the country to carry out work of this nature. The Indian glass and ceramic industries have no specifications for raw materials or finished goods; and it is difficult to expect that specifications followed abroad can be strictly applied to present-day Indian conditions. It is felt that certain standards suitable to Indian conditions should be laid down, and the Institute will help in formulating them and revising them from time to time as the industry progresses.

In the majority of investigations undertaken at the Institute, it is expected that laboratory-scale experiments will suffice; but as the translation of laboratory results into commercial operations often involves aspects not covered by laboratory work, the Institute will carry out investigations on a pilot-plant scale. In this work it is expected that assistance from industrial concerns situated in Calcutta will be readily available.

To fulfil its purpose, it is scarcely necessary to stress the importance of the Institute maintaining the closest relations with the industries in India. Also, being a central organisation engaged in glass and ceramic technological work, it will keep in contact with similar organisations abroad.

Staff

The wide and exacting functions of the Institute demand that the directing staff, apart from possessing high scientific abilities, should be able to inspire a spirit of team-work and create an enthusiasm for it, and the Council is fully alive to these requirements. Although ultimately the Institute will have separate sections for glass, porcelain, enamels and refractories, during the period of organisation it will function largely on a composite basis; and it is rather early to say, at this stage, what will be the full complement of technical or other staff; but it is hoped that in the final stages the senior technical staff of the Institute will consist of a director in charge of the Institute with two assistant directors and three research officers specialized in different branches. To assist them there will be five junior research officers and a number of research assistants and research students. In the appointment of the staff, care will be taken to ensure that all branches of glass and ceramic technology are well represented, so that investigations on all aspects can be successfully conducted by those qualified for the work.

The foundation stone of the Central Glass and Ceramic Research Institute was laid by the Hon. Sir Ardeshir Dalal, Member for Planning and Development, Viceroy's Executive Council, on December 24, 1945.

SECRETION OF RED BLOOD CORPUSCLES

By Dr. FREDERIC DURAN-JORDA

Director of the Pathology Department, Ancoats Hospital, Manchester 4

STUDYING the problem of hæmopoiesis, we arrived at the conclusion that the red blood corpuscle was a product of secretion by a monoglandular cell, which, when present in the peripheral blood, has been classified as a polymorph eosinophil[1]. At that time, however, we were unable to demonstrate fully how this red blood corpuscle secretion could be seen objectively by research workers.

Since then, however, we have been able to see this red blood corpuscle secretion clearly in the hæmorrhagic cysts present in some thyroid glands, and also to appreciate its significance by using similar methods to those we have previously described in the study of fat secretion in milk and pus formation[2].

The process of hæmopoiesis in mammals takes place in two stages, which can both be studied objectively.

The first stage is the formation of the granules in the cytoplasm of the cell, which will become preformed red blood corpuscles. This phenomenon takes place in man in the stomach and intestines, and can be examined easily in the abomasum of the Herbivora, cattle and sheep[3].

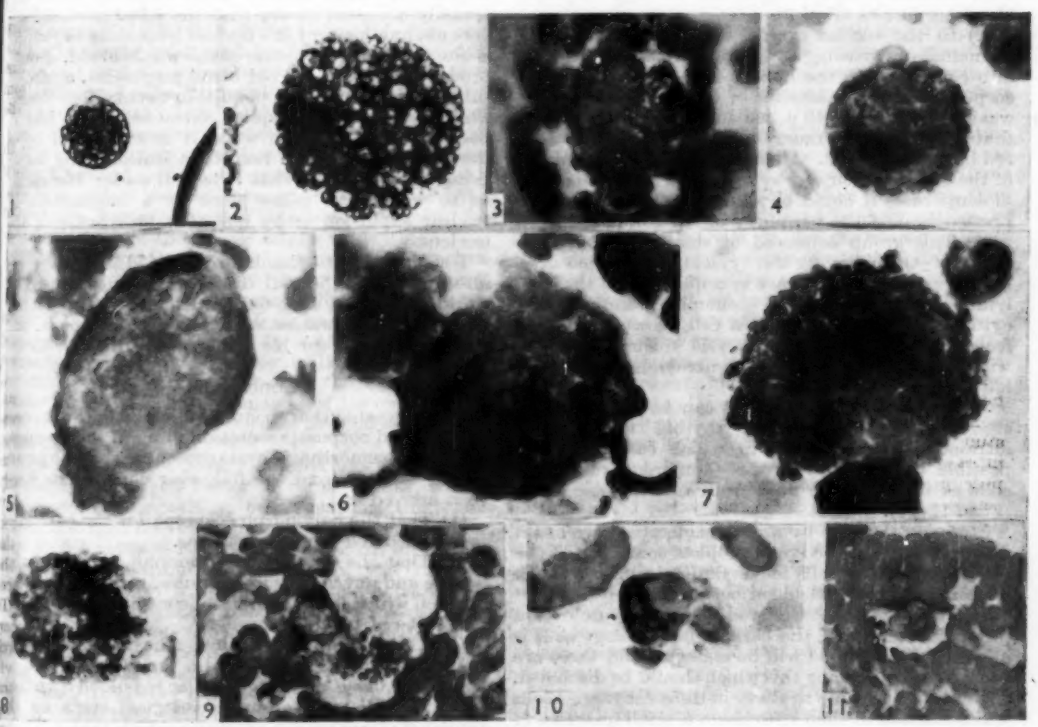
The second stage, the secretory one, is the stage by which the cell, from the aspect of a polymorph eosinophil, develops into a cell of a very large size, which eventually, after expelling the red blood corpuscles, shrinks and becomes a lymphocyte.

The hæmorrhagic cysts present in some thyroid glands were punctured immediately after thyroidectomy, using a capillary pipette which filled spontaneously with hæmorrhagic fluid. Part of this fluid was mixed with saline solution containing 1 per cent of 3·8 per cent sodium citrate solution, and added to the mixture were a few drops of methylene blue. The remainder of the contents of the capillary pipette were made into dry smears, which were stained with May–Grunwald Giemsa. In the wet films, we found that we could divide the cellular contents into three groups, as we had observed in the study of milk and pus.

(1) The first group was formed by what appeared to be polymorphonuclears which had a cytoplasm full of lipoid droplets with the same appearance as eosinophils in wet films (Fig. 1).

(2) The second group consisted of mononuclears which attained a tremendous size of more than 40 μ in diameter, and contained lipoid droplets in their cytoplasm, which were more homogeneous in size than those found in our previous studies of milk and pus cells, and reached a maximum size corresponding to a red blood corpuscle (Fig. 2).

(3) The third group consisted of smaller mononuclears which contained a fewer number of droplets



SMEARS STAINED WITH MAY–GRUNWALD GIEMSA

1 and 2, Wet films of thyroid fluid, showing one cell with the aspect of a polymorph eosinophil, and another cell in full development; 3, polymorph eosinophil containing very large granules; 4, a mononuclear containing granules of eosin-like small red blood corpuscles; 5, a mononuclear with a nucleus compressed against the edge of the cell; 6 and 7, large cells filled with about 200 red blood corpuscles; 8, a cell in the process of shrinking and expelling red blood corpuscles; 9, a cell after shrinking which still contains granules of eosin; 10, lymphocyte showing a double feature—a lymphocytic nucleus and a fully developed red blood corpuscle (notice that the lymphocyte still contains some granules of eosin); 11, lymphocyte with one granule of eosin.

SECTIONS STAINED WITH HÆMATOXYLIN AND EOSIN

12, Section from intra-acinar hæmorrhage in a thyroid (notice cells of different sizes containing red blood corpuscles); 13 and 14, high magnification of two cells full of red blood corpuscles; 15, a cell in the process of expelling red blood corpuscles and shrinking.

and occasionally red blood corpuscles. Some of the cells were like a lymphocyte with a cytoplasm still containing a few lipoid granules.

Studying the dry, stained films, the evolution of the cells could be easily observed, as in this case the material which the cell contained was not dissolved by the alcohol used in the stain, and we could, therefore, follow the evolution of the cells easily in all the intermediary stages.

Again, our findings could be classified into three groups of cells.

(1) The group formed by different sizes of polymorph eosinophils which contained granules varying from normal eosinophil granules to very tiny red blood corpuscles (Fig. 3).

(2) In the second group, there was a range of mononuclears growing to a gigantic size, and, taking into consideration the normal size of one red blood corpuscle and the diameter of the large cells, which was approximately 40 μ, we could estimate roughly that the largest cells must contain about two hundred red blood corpuscles. All the space in the cytoplasm of the cell was occupied by red blood corpuscles, and in some cases it could be seen how the nucleus was pressed against the periphery of the cell (Figs. 4–8).

(3) This group consisted of small mononuclears, some of them having the typical appearance of a lymphocyte; in which case it could be seen that the lymphocyte still contained eosinophil granules in the cytoplasm, or occasionally a cell showed a double feature, namely, a lymphocytic nucleus together with a red blood corpuscle, all surrounded by a small halo of cytoplasm (Figs. 9–11).

These previous observations can be confirmed by studying some sections of thyroid which show intra-acinar hæmorrhage, in which case it is also possible to study these three different ranges of cells as found in the fluid from hæmorrhagic cysts (Figs. 12–15).

Studying the cells by micro-incineration, we could demonstrate that the lipoid droplets contained in the cytoplasm of the cells leave similar ash to the ash deposited by the red blood corpuscles.

If we accept that the red blood corpuscle is a product of secretion, the basis of hæmatology as it is at present understood will be changed, and there are some facts concerning this which should be discussed.

Biologists are able to study in different tissues cells which contain in their cytoplasm a small quantity of red blood corpuscles, and they have interpreted this as a phenomenon of phagocytosis; but if a cell contains about two hundred red blood corpuscles, which completely fill its cytoplasm, there is no room left for their digestion.

It is very surprising to find that our observations of red blood corpuscle formation and secretion by a monoglandular cell are similar to the observations made by Kolliker in 1854[4]; Kolliker describes how cells which contained in their cytoplasm a large quantity of red blood corpuscles shrunk until they became a small granulated cell (? eosinophil). Kolliker, therefore, saw the same thing we have described, but did not interpret it in the same way.

If the life of the red blood corpuscle is a hundred days, the daily development of approximately 250 polymorph eosinophils per cub. mm. will be enough to make good the wear and tear of the red blood corpuscles. This is more understandable than the actually accepted theory that the 5,000 normoblasts per cub. mm. present in a normal bone marrow, which is one third of the volume of the whole blood, should produce daily 150,000 red blood corpuscles, a rate of thirty mitotic divisions per cell in twenty-four hours. This fact in itself is quite extraordinary; but it becomes even more so when it is supported by a process of maturation and denucleation, this latter being so mysterious that it is still under discussion as to whether it takes place by a mechanism of nuclear expulsion or by one of karyorrhexis of the nucleus.

I should like to thank Prof. Wood Jones for his interesting and helpful discussions concerning this work. Also the surgeons of Ancoats Hospital for their kind co-operation with surgical specimens, and Mr. J. B. Dean for his assistance with the photomicrographs.

Conclusions

It is suggested that to study objectively the process of red blood corpuscle secretion in man, the hæmatic fluid from hæmorrhagic cysts present in some thyroids should be used, and the following conclusions have been arrived at.

(1) That the polymorph eosinophil is the carrier of pre-formed red blood corpuscles.

(2) That the polymorph eosinophil, by increasing its size and developing its granules, reaches the stage of a cell which has a cytoplasm containing about two hundred red blood corpuscles.

(3) The cell, after expelling the red blood corpuscles, shrinks and becomes a lymphocyte.

(4) This cycle of monoglandular red blood corpuscle secretion follows the same biological steps as the similar monoglandular processes which take place in the secretion of fat milk, and pus formation.

[1] Duran-Jorda, F., *Lancet*, 186 (August 14, 1943).
[2] Duran-Jorda, F., *Nature*, **154**, 704 (1944); **156**, 110 (1945).
[3] Duran-Jorda, F., *Vet. J.*, **101**, No. 9, 191 (1945).
[4] Kolliker, "Human Histology", vol. 2 (1854).

SCRUB TYPHUS AS A STUDY IN ECOLOGY*

By Lieut.-Colonel J. R. AUDY, R.A.M.C.
Scrub Typhus Research Laboratory, S.E.A.C., and London School of Hygiene and Tropical Medicine

MITE-BORNE scrub typhus (tsutsugamushi disease) was a serious military problem in the Japanese campaign, and units unlucky enough to strike endemic foci suffered heavily[1]. The epidemiology of the disease was investigated in North Burma by the U.S. Typhus Commission, and in the Imphal area (Manipur, Assam) by a team based on the Scrub Typhus Research Laboratory, which attempted to do complementary work, particularly on the ecology of the disease.

The general findings of this team are shortly to be published, but this present note concerns an interesting aspect of its investigations, namely, the way in which light may be thrown on the ecology and behaviour of small mammals by a study of their infestation by Trombiculid mites.

This is possible because the Trombiculid mites are partly soil-bound: the non-parasitic nymphal and adult stages spend their lives in the soil, while the larvæ alone parasitize warm-blooded animals. The larvæ feed but once before returning to the soil for metamorphosis, the feed lasting from four days to several weeks according to the species. These mites have actually to be introduced to suitable foci, and will continue to infest such foci only if hosts pick up larvæ and return a proportion to the same place, thus maintaining a mite–mammal–mite cycle related to a patch of ground which may be far from the actual nest of the mammal. These mites are not conspicuous within or around rat-burrows, but appear to be liberated and picked up around feeding-places. There is a close parallel between these mites and the jigger flea *Tunga penetrans*, the larvæ of which are soil-bound while the female adults attack man.

Even though the larvæ can move quickly when stimulated, the range of movement of both larvæ and adults appears to be greatly limited, so that a heavily infested spot may adjoin an almost mite-free area a yard or two away. It is clear that such a parasite can serve as an ecological label, especially if its distribution is restricted or if the non-parasitic phase makes ecological demands of its own on the soil, which appears to be the case to a varying degree with different species.

The species most closely studied was *Trombicula deliensis* Walch, the vector of scrub typhus, while, for numerical as well as other reasons, the most important host for this and most other Trombiculids was *Rattus rattus* in its local varieties. An investigation of the distribution, population, and rate of turnover (namely, the number of larvæ becoming attached to rats daily, related to the short time, 3–5 days, spent on the host) indicates with little doubt that this species is the most successful Trombiculid ectoparasite of rats in the whole of the Far East. It is very closely related to *T. akamushi*, which shares part of its distribution in Malaya, New Guinea and the Philippines, and is the classical vector of tsutsugamushi in Japan.

That Trombiculid mites occur in 'islands' related to a restricted range of the principal host was illustrated several times, but particularly while trapping in a series of plots 50 yd. × 50 yd. in a strip transecting a large expanse of scrub near Imphal during December–January 1946, when 109 rats were caught. For the first 400 yards, 32/50 of the infested rats (*Rattus rattus* var.) caught carried apparently pure cultures of *Ascoschöngastia mutabilis* Gater, 1932, while a few were infested by this species mixed with a congeneric but distinct species, *A. kohlsi* Philip and Woodward, 1946, and only one rat with *A. kohlsi* alone. For the next 200 yards, 27/36 (75 per cent) were infested by a mixture of both species, while for the last 150 yards to the end of the transect, 20/23 (87 per cent) were infested by pure cultures of *A. kohlsi*, and not one by *A. mutabilis* alone. The existence of two such 'islands' of infestation by these two species, overlapping for less than 200 yards, is in this particular instance explicable by the restricted range of the rats in the rank scrub. The two species concerned remain attached to rats for a week or more: they are picked up and, after that time, dropped on to the ground near by. This restriction of range was illustrated in this same area by the trapping on two occasions of a grey rat (at present unnamed) which could be distinguished from the common species: in one of the plots, six of the eight rats caught were grey, and were all trapped within a circle of 30 yd. diameter, while near by three rats of the same grey species were caught one day in three adjacent traps.

It will be understood that these two overlapping 'islands' of infestation are not a picture of a permanent state, but of a stage in a dynamic situation. The rate at which the zone of overlap expands in both directions depends particularly upon the range of movement of the rats.

There are many examples of differential infestation of rats in contiguous areas. Gater[2] noted that two common Malayan mites, *T. munda* and *Gahrliepia fletcheri*, appear to be more common in villages than elsewhere. We found an undescribed species of *Schöngastiella* to have a similar distribution. Rats (239 *R. rattus* var. in October–November 1945) were trapped in Mongjam village near Imphal, and 87 per cent were infested by this species, while of these 44 per cent were 'pure cultures', showing that nearly half the rats were exposed to fairly uncontaminated 'islands' of infestation by this species. The infestation of these village rats by *T. deliensis* was 40 per cent, only 17 per cent of these being pure cultures. This contrasted with the findings in rats of the same species trapped in hill-foot scrub a few hundred yards away across a belt of rice-fields, where only 30 per cent were infested by *Schöngastiella* (26 per cent pure cultures), and 90 per cent by *T. deliensis* (64 per cent pure cultures). It is likely that the considerable evacuation of the village by the natives, which coincided with the establishment of military camps in the hill-foot area in 1942–43, led to a migration of a number of rats from the village to the camps, and to the seeding out of many colonies of *Schöngastiella*. This species remains attached to its host for a month or more.

The influence on the mites of the high rat population which frequented the scrub immediately on the edge of a camp was investigated by laying down lines of rats in small cages and counting and identifying the mites which they picked up in twenty-four hours. It was found that there was a rapid and significant increase in mite population as the immediate perimeter of the camp was approached.

* Published by permission of the Army Medical Directorate, War Office.

A similar investigation transecting the junction between grassy scrub and a strip of forest following a water-course showed a significant and high population of mites in the narrow intermediate belt of dense vegetation between open scrub and forest. Such ecotones have repeatedly been associated with scrub typhus: we have been calling them 'fringe-habitats', and including hedgerows as a special case within this category.

The seasonal changes in vegetation were found to be considerable, to be related to seasonal variations in behaviour and population of the rats, and to be very intricate. Even so, some useful light was thrown on this complex picture by a study of the infestation of the rats, although the following discussion is intended to suggest ways in which this can be done and not to present a picture of what was actually happening in the Imphal area, where our investigations were very greatly limited and, in ignorance, not properly designed to this end.

T. deliensis, like *T. akamushi*, is a seasonal mite, in that the larvæ become very scanty during the dry season, whereas they appear in great numbers shortly after the onset of the rains. The 1945–46 inter-monsoon period in Imphal was unusually dry; but even so, at its height larvæ of *T. deliensis* could always be recovered from foci on seepages or by perennial streams which were kept moist by ground water, while they had almost completely disappeared from exposed dry sites. At such a time, it is possible to use this species in selected areas as an index of the host behaviour in relation to water-points, as well as an indicator of the behaviour of the hosts during the different seasons. This, however, needs very extensive collections: only one application appears to be worth while with the Imphal material, and that is to group the rats according to intensity of infestation (0, 0–10, 10–50, 50–100, 100–200, and more than 200 mites per rat), and to study the frequency of distribution of the rats within these groups month by month, in conjunction with the rate and average intensity of infestation. As this can be done only with pure cultures of the species, *T. deliensis*, being investigated, it is clear that we are dealing with a selected sample of rats exposed on fairly uncontaminated '*deliensis* islands'. This study shows that with the first flood of larvæ which appeared after the rains broke in May 1945 there was a very high rate of infestation (more than 70 per cent) but a relatively low intensity, most of the rats being in the 10–50 mites-per-rat group. Two or three months later, there was a distinct shift in distribution from the low-intensity groups to the highest. At the height of the following dry season, the rate of infestation fell from more than 60 per cent to less than 10 per cent, and particularly the lowest and the highest intensity groups were represented. This *suggests* either an initially dispersed appearance of larval mites, or a wide and variable range of movement of the rats, or more probably both, followed later probably by a second generation of larvæ in more compact conditions of association between mite and rat. Later still, the larvæ were scarce and a few rats remained heavily infested because they were in moist foci where the larval population was being maintained.

All these findings have a bearing on the ecology of scrub typhus itself. The disease is very sharply localized, and has an ecology of its own, which is related to vegetation and terrain but not directly to any specific plant, although most of the typhus appears to reside in rank grassy undergrowth, on waste-land or water-meadows, or in the fringe-habitats at the edge of such tracts.

It is considered that a planned study of the Trombiculids infesting rodents and shrews, as well as the other ectoparasites such as fleas and gamasid mites which appear to be related to the *domestic* habits of the hosts, is an economical method of investigation, because it throws as much light on the mammals as it does on a variety of ectoparasites. It is a synecological approach.

[1] Buxton, P. A., *Nature*, **155**, 643 (1945).
[2] Gater, B. A. R., *Parasitology*, **24** (2), 140 and 163 (1932).

OBITUARY

Prof. A. A. Glagoleva-Arkadieva

A YEAR has passed since the death on October 30, 1945, of Alexandra Andreevna Glagoleva-Arkadieva, professor of physics at the University of Moscow. Prof. Glagoleva-Arkadieva was born in 1884. Upon leaving a secondary school in Tula, she worked as a country school-teacher during 1900–6. In 1910 she completed the Moscow Higher Courses for Women, where she studied physico-mathematics, attending lectures by Prof. A. A. Eichenwald and N. A. Umov, the physicists. Following her graduation she became an assistant in physics at the courses, which after the Revolution of 1917 were reorganised into the Second University of Moscow.

During the First World War, Glagoleva-Arkadieva organised an X-ray room at the war hospital belonging to the Higher Courses, where she designed and built an instrument called the roentgenostereometer for determining precisely the location of bullets or shell splinters in the human body. The fundamental theory of this instrument, which enabled an observer to make precise measurements of depth at any ocular distance, was worked out by the designer herself. After the War the instrument found application in midwifery. With her wealth of practical experience, Glagoleva-Arkadieva for a number of years gave a highly popular lecture course in X-rays for medical men and students.

In 1920, Glagoleva-Arkadieva initiated research in the J. C. Maxwell Laboratory at the University of Moscow on the generation of millimetre electric waves, which was necessary for the study of magnetic properties in the frequency range in which an abrupt drop in permeability of iron and nickel approaching unity had been detected in 1912. Already in 1922 she was able to report to the convention of Russian physicists on a mass radiator, on a new source of ultra-short electric waves. This source, which she described in 1924 in a communication in *Nature* (May 3, 1924, p. 640), made it possible to obtain wave-lengths from several centimetres to 82 microns. Her method consisted in passing electric sparks through a mixture of filings and viscous oil (vibrational mass). The new rays she obtained more than filled the gap between radio-waves and the long infra-red waves of Rubens that had remained in the wave scale since the time of O. Lodge and P. Lebedev. The ease of obtaining interference curves of the waves of the mass radiator pointed to the formation of undamped very short waves during spark discharges; this was corroborated by Leontieva in 1925, and more recently by H. G. Kelliher and E. T. S. Walton.

The distribution of the radiating power on the surface of the vibrational mass of the mass radiator—

the spectral composition of the radiation at its various points—was investigated by Glagoleva-Arkadieva in 1928. Simultaneously, with the aid of her wave detector thermo-element, she investigated the long-wave radiation of the mercury lamp. Since she employed a Boltzmann interferometer, she obtained a symmetrical interference curve, which was 2·5 times longer than that obtained by previous investigators; the curve gave a wave-length of 340 microns.

During 1932–33, A. A. Glagoleva-Arkadieva, employing an echelette grating, isolated from the mixed radiation of the mass radiator pure waves ranging from 9·9 mm. to 350 microns in length. In 1937 she developed a method of reticulate filters making it possible to isolate bands of definite width. The method is based on the utilization of Hertz gratings folded crosswise. The last ten years of her life found her studying the mechanism of the mass radiator and developing its theory of operation. She established that filings of irregular shape are more effective than spherical ones, and that the smallest particles still giving vibrations had a length of 0·02 mm. She showed that in the radiation of the mass radiator there are three principal waves: one conditioned by vibrations in individual grains (as in the sphere of the Lodge vibrator); another by the vibrations of a pair of grains (as in the Lebedev vibrator); while the third wave depends upon the design of the apparatus and arises from the vibrations in the chains of particles that form in the vibrational mass when sparks jump across. Her mass radiator has been applied to measurements in the field of millimetre waves, which other generators of electric vibrations do not produce.

A. A. Glagoleva-Arkadieva was able to combine her outstanding research with extensive teaching and other activity. Only in 1937, on medical advice, did she resign her position as head of a department at the Second Moscow Medical Institute, and in 1939, at the University of Moscow. She trained many teachers, medical radiographers and research workers, who have high praise for her power to imbue a love for science. By decision of the Academy of Sciences of the U.S.S.R. a collection of the papers of A. A. Glagoleva-Arkadieva is to be published.

S. Vavilov
A. Ioffé

NEWS and VIEWS

Alexander Graham Bell (1847–1922)

The name of Alexander Graham Bell, who was born in Edinburgh on March 3, 1847, will always be associated with two memorable achievements: the invention of the telephone and the education of the deaf. His interest in the human voice was inspired by his father and grandfather, both authorities in phonetics and elocution. From his mother he inherited a remarkable appreciation of tone values. In 1868 he began to teach his father's system of 'visible speech' for the deaf at a school in Kensington. Two years later he accompanied his parents to Canada, and in 1873 he was appointed professor of vocal physiology at Boston University. It was his simultaneous study of the air waves in the ear during the utterance of voice sounds, and of a tuned system of multiple telegraphy, which led to the invention of the telephone. In June 1875 he made his first telephone at Boston, and on March 10, 1876, sent the first intelligible message: "Mr. Watson, come here; I want you". His novel machine was demonstrated before the American Academy of Arts and Sciences in Boston two months later, and was introduced to the world at the Philadelphia Centennial Exhibition. The Bell Telephone Company was inaugurated in the following year. With the Volta Prize of 50,000 francs awarded by the French Government in 1880, Bell financed the Volta Bureau in Washington for the increase and diffusion of knowledge relating to the deaf. Interested in the subject of marriage of the deaf, he took up the study of eugenics, while after 1895 aviation chiefly engaged his attention.

This issue of *Nature* (dated March 1) and also that dated February 22 were not printed until after the restrictions on the use of electric power were removed on March 3

National Research Council, Canada: Appointment of Dr. David A. Keys

Dr. David A. Keys, Macdonald professor of physics at McGill University, has been appointed vice-president of the National Research Council, Canada, in charge of the atomic energy establishment at Chalk River, Ontario. The National Research Council has now taken complete responsibility for the operation of this undertaking. Hitherto, the National Research Council was responsible for the Research Division on Atomic Energy, of which Dr. W. B. Lewis is director, but Defence Industries Ltd. was in charge of the construction and operation of the industrial, pilot plant facilities and the village of Deep River. Dr. Keys has had a long and impressive experience in research, scientific education and administration. Born in Toronto, he attended Upper Canada College and had a brilliant record at the Universities of Toronto and Cambridge and Harvard University. He joined the staff of McGill University in 1922.

National Research Council for Natural Sciences in Sweden

In addition to the already existing National Research Councils for Technology, for Medicine and for Agriculture, a new Research Council for Natural Sciences has recently been established in Sweden by a royal charter. The new Council will have as its most important task the distribution of funds for fundamental research in the natural sciences and mathematics and the granting of fellowships for scientific studies and expeditions abroad. The Council will also encourage and support work for the international relations of Swedish research workers and institutions. The Swedish Parliament has granted one million Swedish crowns to the Council for the present fiscal year. The president (Prof. Arne Tiselius, Uppsala) and two other members (Prof. T. Caspersson and Prof. Bo Kalling, Stockholm) are appointed by the King. The other four members of the Council are Prof. B. Lindblad, elected by the Royal Academy of Sciences, Prof. E. Melin, elected by the University of Uppsala, Prof. B. Edlén, elected

by the University of Lund, and Prof. K. Myrbäck, elected by the University of Stockholm. The secretary is Dr. G. Funke, and the address is Statens Naturvetenskapliga Forskningsråd, Besmansvägen 10, Åkeslund (Stockholm). One of the first actions of the Council has been to extend an invitation to Prof. D. R. Hartree, of the Cavendish Laboratory, Cambridge, to visit Sweden and to lecture on modern calculating machines.

British Society for the History of Science

On November 22, 1946, a meeting of persons interested in the history of science was held at the Science Museum, South Kensington. The purpose of the meeting was primarily to consider how Great Britain could best associate itself with the International Academy for the History of Science, which is about to seek affiliation with the International Council of Scientific Unions. After some discussion, it was unanimously decided that a History of Science Society should be formed, which could act as a national group and so fulfil one of the conditions necessary for association with the International Council. A committee was thereupon appointed to draw up a draft constitution for such a society. This Committee reported its recommendations to a further meeting of the original body on February 12, and as a result a provisional constitution was adopted, of which the following are the chief points.

The society is to be known as the British Society for the History of Science, and its objects are to further the study of the history of science (*a*) by meetings for the reading and discussion of papers; (*b*) by facilitating the publication of relevant material; (*c*) by co-operation with other interested bodies; and (*d*) by any other means that the Council of the Society may consider desirable. Membership is to be open to all interested in the subject who satisfy certain formal conditions, on payment of a subscription which for the first year is to be one guinea. The committee which drafted the constitution is to remain in office until the first annual general meeting, which is to be held in May next, when officers and council are to be elected. The provisional honorary secretary is Mr. F. H. C. Butler, "Ravensmead", Keston, Kent. He will be glad to hear from any who wish to become members. Steps for making the existence of the Society known are under consideration, and a statement will be issued in due course.

A Biological News-Letter

Biologists will be interested in the new Monthly News Letter *Biologia* which Dr. Frans Verdoorn is publishing as a supplement to *Chronica Botanica*. The intention is that this News Letter should be kept small and informal, as previous experience has shown that more extensive news magazines tend not to be read and well used by those for whom they have been prepared. It is the intention in *Biologia* to print information relating to methodological and professional aspects of biology rather than to publish special articles or subjects for discussion. In the first issue, that for January 1947, biologists will find much contemporary information which they might otherwise, in a busy life, tend to overlook. It contains, for example, brief references to a wide range of current biological activities such as UNESCO's first general conference, notices of various scientific congresses and meetings, new editions of such books as "The International Rules of Botanical Nomenclature", the International Zoological Station at Naples, a list of research scholarships, fellowships and grants supported by industry in the United States, scientific institutions in the Ukraine, and so on. The biological world thus owes a further debt of gratitude to Dr. Verdoorn for his many activities in their interest.

A New Heat-absorbing and Heat-resisting Glass

The German name for the focus of a lens, *Brennpunkt*, records an observation that is only too well known to both professional and amateur cinema operators. All our ordinary sources of white light radiate a large amount of energy at 'infra-red' frequencies, and a material such as a film placed in the image of a strong source may readily absorb this energy even if it transmits most of the visible light, and be likely to burn unless the exposure is very short. Various efforts have been made to avoid this trouble by producing a filter which will remove the infra-red while transmitting the visible. Water-cells are sometimes employed, but they are inconvenient and not very efficient. The late Sir William Crookes experimented with various glasses. One which he produced had a good infra-red absorption, but had a strong green colour in any thickness more than about 2 mm.; it was said to contain iron in the ferrous condition. One of the troubles with glasses of this kind is that they are subject to marked heating; and unless the filter is uniformly illuminated and heated there must be unequal expansion. Unless the material has a low thermal expansion it may crack.

Messrs. Chance Bros., Ltd., have recently produced a new heat-absorbing glass, *ON* 19, which represents a considerable advance on one previously listed in their catalogue. If the source is an ordinary gas-filled lamp of the projection type, it is claimed that, at a thickness of 6·0 mm., a sheet of this glass will transmit 81 per cent of the visible light, but only 4·5 per cent of the heat; it is said to be virtually colourless, and of good durability, moreover, having good heat-resisting properties. For use in projection systems, it is suggested that it should normally be placed near the condensers, on the side of the lamp; some form of forced cooling is usually necessary. The filter can sometimes be cut into strips further to reduce the risk of fracture. The glass is stocked in rolled sheets, 5–6 mm. in thickness. It is likely to contain scattered fine bubbles and is not intended for optical use other than as a filter. It should find many useful technical and scientific applications.

Royal Astronomical Society: Officers

The following have been elected officers of the Royal Astronomical Society: *President*, Prof. W. M. H. Greaves, Astronomer Royal for Scotland and professor of astronomy in the University of Edinburgh; *Vice-Presidents*, Miss M. G. Adam, chief assistant (astronomy), University Observatory, Oxford; Dr. M. Davidson; Prof. H. H. Plaskett, Savilian professor of astronomy, University of Oxford; D. H. Sadler, superintendent of the Nautical Almanac; *Treasurer*, Sir Harold Spencer Jones, Astronomer Royal; *Secretaries*, Prof. W. H. McCrea, professor of mathematics, University of London (Royal Holloway College); Dr. A. D. Thackeray, assistant director, Solar Physics Observatory, Cambridge; *Foreign Secretary*, Prof. F. J. M.

Stratton, professor of astrophysics and director of the Observatories, University of Cambridge; *Council*, Dr. R. d'E. Atkinson, chief assistant, Royal Observatory, Greenwich; B. C. Browne, lecturer in geodesy, University of Cambridge; Dr. H. A. Brück, John Couch Adams astronomer, and assistant director of the Cambridge Observatory; D. L. Edwards, director of the Norman Lockyer Observatory, Sidmouth; Dr. M. A. Ellison; C. C. L. Gregory, director and Wilson observer, University of London Observatory; F. Hoyle, lecturer in mathematics, University of Cambridge; Dr. A. Hunter, assistant, Royal Observatory, Greenwich; Dr. E. H. Linfoot, lecturer in mathematics, University of Bristol; P. J. Melotte, assistant, Royal Observatory, Greenwich; Prof. E. A. Milne, Rouse Ball professor of mathematics, University of Oxford; Dr. W. H. Steavenson, Gresham professor in astronomy.

Institution of Electrical Engineers Scholarships

THE Council of the Institution of Electrical Engineers is offering the following scholarships: *Research Scholarships:* Ferranti Scholarship (£250 a year for two years); Oliver Lodge Scholarship (£250 for one year); Swan Memorial Scholarship (£150 for one year); C. P. Sparks War Thanksgiving Fund (a grant not exceeding £100 for one year). *Student Scholarships:* Duddell Scholarship (£150 a year for three years); Manville Scholarship (£150 a year for three years); Silvanus Thompson Scholarship (£100 a year plus fees for two years); Salomons Scholarship (£100 for one year); David Hughes Scholarship (£100 for one year); Paul Scholarship (£50 a year for two years); Thorrowgood Scholarship (£25 a year for two years). Particulars and nomination forms, to be returned by April 15 (student scholarships) or June 1 (research scholarships), can be obtained from the Secretary, Institution of Electrical Engineers, Savoy Place, London, W.C.2.

University of Leeds: Appointments

THE following appointments have been made in the University of Leeds: Dr. A. J. Brown, lately fellow of All Souls College, Oxford, to be professor of economics and head of the Department of Economics and Commerce; Dr. A. L. Roberts, senior lecturer in refractory materials, to be Livesey professor of coal, gas and fuel industries; Dr. G. S. Rushbrooke, Brotherton research lecturer in physical chemistry, to be lecturer in mathematical chemistry.

The Night Sky in March

FULL moon occurs on March 7d. 03h. 15m. U.T. and new moon on March 22d. 16h. 34m. The following conjunctions with the moon take place: March 4d. 02h., Saturn 4° S.; March 12d. 15h., Jupiter 0·5° N.; March 19d. 01h., Venus 5° N.; March 20d. 20h., Mercury 7° N.; March 21d. 04h., Mars 4° N.; March 31d. 07h., Saturn 4° S. In addition to these conjunctions with the moon, Mercury is in conjunction with Mars on March 16d. 17h., Mercury being 7° N. Mercury, in inferior conjunction with the sun on March 8, is not favourably placed for observation in the early part of the month. On March 15 the planet rises at 5h. 42m., and on March 31 at 5h. 06m., and can be seen in the eastern sky; but is a difficult object although its stellar magnitude is less than 1 at the end of March, because sunrise takes place only 35 minutes and 45 minutes later on the above dates. Venus is conspicuous as a morning star, rising at 5h. 02m., 4h. 57m., and 4h. 40m., at the beginning, middle and end of the month, respectively. The surface of the illuminated disk varies from 0·643 to 0·736 and the stellar magnitude is about −3·6 during the month. Mars is not well placed for observation. Jupiter can be seen close to β Scorpii, rising at 0h. 48m., 23h. 54m. and 22h. 49m. at the beginning, middle and end of the month, respectively. The mean stellar magnitude of Jupiter is −1·8 during March, and the planet is stationary on March 14. Saturn is visible up to the early morning hours, setting at 5h. 37m., 4h. 39m. and 3h. 35m. at the beginning, middle and end of the month respectively. The planet is easily recognized a little west of γ and δ Cancris, its stellar magnitude being 0·2. Occultations of stars brighter than magnitude 6 are as follows: March 3d. 00h. 20·3m., 52 Gemi. (*D*); March 29d. 22h. 46·8m., 37 Gemi. (*D*). The latitude of Greenwich is assumed and *D* refers to disappearance. In addition to these occultations of stars, Uranus (mag. 6) is occulted on March 1d. 01h. 08·1m. Spring equinox occurs on March 21d. 11h.

Announcements

THE annual Mather Lecture of the Textile Institute will be delivered by Sir Walter Haworth, professor of chemistry in the University of Birmingham, on the occasion of the annual general meeting of the Institute on April 23; his subject will be "The Chemistry of the Polysaccharides".

DR. F. W. HAYWOOD, who has been chief metallurgist of Wild-Barfield Electric Furnaces, Ltd., since 1938, has been appointed to the Board of the Company as technical director.

THE Challenger Society is prepared to consider applications for small grants in aid of research in marine biology or oceanography at a recognized laboratory during the year April 1947–April 1948. Applications, accompanied by details of the proposed research, should reach the honorary secretary, Mr. Dilwyn John, British Museum (Natural History), London, S.W.7, before April 19.

A RADIOCOMMUNICATION CONVENTION, dealing particularly with war-time activities and their possible influence on peace-time development, has been arranged by the Institution of Electrical Engineers, and will be held at the Institution during March 25–28. Sessions will be devoted to such topics as long-distance point-to-point communication; naval, military and aeronautical communication; pulse communication; short-distance communication; direction finding; and war-time broadcasting. Sir Stanley Angwin will deliver an address on "Telecommunication in War".

ERRATUM.—In the letter by Dr. G. Whittingham on "The Luminous Decomposition of Nitrous Oxide", in *Nature* of February 15, p. 232: (*a*) 4 lines from foot of the first column, for "due to nitrous oxide" read "due to nitrogen peroxide"; (*b*) last sentence should read "Both these reactions require a high energy of activation[18], and sufficient nitric oxide to give a visible glow with the atomic oxygen present is not produced until high temperatures are attained".

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

Gyro Interaction of Radio Waves

A THEORY of the interaction of radio waves in the ionosphere, first reported by Tellegen[1] in 1933 and afterwards observed by many others, was given by Bailey and Martyn[2]. According to this theory, the modulation M impressed by the interfering long-wave station on the medium wave-length transmission reflected from the ionosphere in the vicinity of the long-wave station is

$$M = \text{const.} \frac{PD}{\sqrt{1 + \left(\frac{n}{G\nu_0}\right)^2}}, \quad . \quad (1)$$

where P is the power, D the depth of modulation and $n/2\pi$ the modulation frequency of the long-wave station. ν_0 is the collision frequency of an electron in thermal equilibrium with the gas molecules in that portion of the E-layer traversed by the wave of medium wave-length. The quantity G is a constant which relates the mean fractional loss of energy of $\overline{\lambda}$ of an electron in collisions with molecules of the gas to the collision frequency ν in a state of motion where the mean energy of agitation of the electrons slightly exceeds that of the gas molecules.

According to Pidduck and Bailey,

$$\overline{\lambda} = G\left(1 - \frac{\nu_0^2}{\nu^2}\right). \quad . \quad . \quad . \quad (2)$$

The laboratory experiments of Townsend and Tizard[3] give $G = 2{\cdot}6 \times 10^{-3}$ for ordinary air, but G may well have a different value in the E-layer.

Expression (1) for the impressed modulation was found by Bailey and Martyn[4] to fit the quantitative observations of van der Pol and van der Mark, with $G\nu_0 = 780$.

According to the first formulation of the theory of Bailey and Martyn, the impressed modulation M, other factors remaining the same, should diminish with the wave-length of the interfering station and should be negligible in practice when the interfering station operates on a medium wave-length. Afterwards, Bailey published[5] a revised theory according to which strong interaction, still described by formula (1), is to be expected when the interfering station operates on or near the gyro-frequency $\omega_0/2\pi = Be/2\pi m$, where B is the total intensity of the earth's magnetic field in the E-layer. Although qualitative observations of this gyro-interaction have been reported[6], it was considered desirable, in view of the practical importance of the phenomenon, both in setting a possible upper limit to the power of a broadcast station operating near the gyro-frequency, and also as a tool for ionospheric research, to carry out some quantitative tests of the theory. The tests, the results of which are given below, were made possible through the courtesy of Mr. H. Bishop, controller of engineering, and of the Engineering Research Department of the British Broadcasting Corporation.

In both tests long-wave transmissions from Droitwich (200 kc./s.) were observed at Dundee after reflexion from the ionosphere to the south (as required by the theory) of the interfering station at Stagshaw (1,050 kc./s.), near Hexham in Northumberland. In the first test, carried out during 0000–0200 B.S.T. July 18, 1946, the existence of the phenomenon of gyro interaction was confirmed and was observed at Dundee using a commercial broadcast receiver, with transmissions from the low-power station at Stagshaw (10 kW. at 1,149 kc./s.)—the gyro-frequency being 1,170 kc./s. Much stronger interaction over the range of audible modulation tones 100–900 c./s. was observed with the higher-power transmitter at Stagshaw (120 kW. at 1,050 kc./s.).

The second series of tests, carried out early in November 1946, was designed to check the validity of formula (1), using the higher-power transmitter at Stagshaw, and Droitwich (200 kc./s.).

Formula (1) may be written,

$$n^{2\prime} = \frac{(\text{const.})^2 (G\nu_0)^2 P^2 D^2}{M^2} - (G\nu_0)^2. \quad . \quad (3)$$

Thus, if the theory be correct, a linear relation should exist between the square of the angular frequency and the square of the reciprocal of the depth of the impressed modulation.

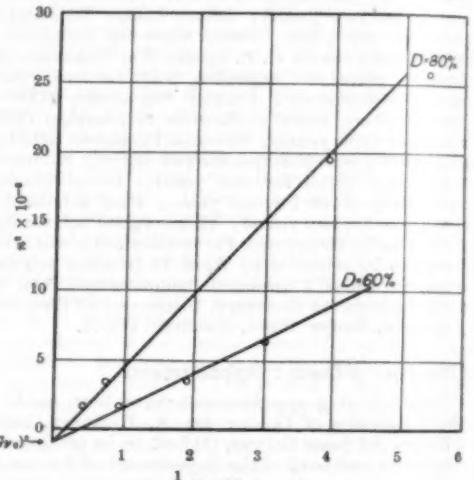


Fig. 1

Fig. 1 shows how the experimental observations accord with expression (3). It can be seen that the points corresponding to a power $P = 120$ kW. and depths of modulation $D = 80$ and 60 per cent lie near straight lines the common intercept of which with the n^2-axis is $-(G\nu_0)^2$. The value of $G\nu_0$ found from the intercept is $G\nu_0 = 950$.

Unfortunately, the accuracy of the measurements at the lower powers P and modulation depths D were poor owing to interference from a distant Russian station operating on the Droitwich wave-length. The points plotted in Fig. 1, however, represent trustworthy measurements.

A further test of the theory was also made. It is implicit in the theory, although not stressed by Bailey, that, accompanying the impressed modulation M given by (1), there is an impressed modulation at the octave frequency ($2n/2\pi$) the depth of which, M_{oct}, is related to M as follows:

$$R = \frac{M_{oct}}{M} = \frac{D}{4}\left[\frac{n^2 + (G\nu_0)^2}{4n^2 + (G\nu_0)^2}\right]^{1/2}, \quad . \quad (4)$$

whence, $$\frac{1}{n^2} = \frac{3}{(G\nu_0)^2\left[\left(\frac{D}{4R}\right)^2 - 1\right]} - \frac{1}{(G\nu_0)^2}. \quad (5)$$

Fig. 2 gives the line representing $1/n^2$ as a function of $1/\left[\left(\frac{D}{4R}\right)^2 - 1\right]$ assuming $G\nu_0 = 950$, from the first measurements. The line is completely determined by $G\nu_0$ since it cuts the horizontal axis at a distance $\frac{1}{3}$ from the origin and the vertical axis at a distance $-1/(G\nu_0)^2$.

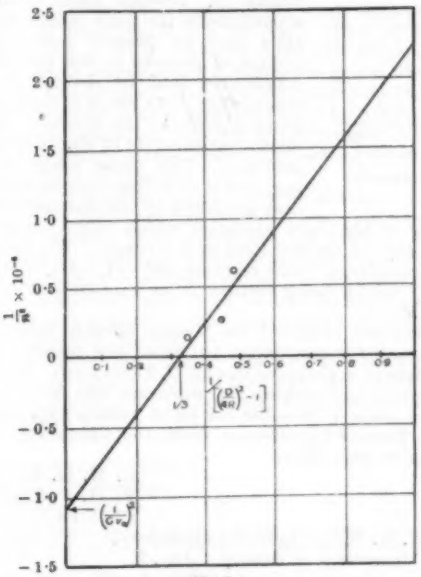


Fig. 2

Measurements of $R = M_{oct}/M$, with $P = 120$ kW. and $D = 60$ per cent, were made at $n/2\pi = 200$, 300 and 400 c./s., using a harmonic analyser.

Reference to Fig. 2 shows that the experimental points lie very near the line corresponding to $G\nu_0 = 950$; $\left(\frac{1}{(G\nu_0)^2} = 1{\cdot}1 \times 10^{-6}\right)$. A third harmonic was also detected.

On the basis of these tests and of Bailey's theory, the modulation observed at Dundee is represented by the formula

$$M = 7{\cdot}8 \times 10^{-4} \frac{PD}{\sqrt{1 + \left(\frac{n}{950}\right)^2}},$$

where P is in kilowatts, M and D in percentages.

These investigations are of a preliminary character, and it is proposed to continue the work. From these results we estimate that if Stagshaw had operated on the gyro-frequency the impressed modulation at 100 c./s. would have been as great as 13 per cent with a transmitted power of 120 kilowatts. Such a station could, therefore, seriously interfere with other transmissions. We are indebted to Mr. J. A. Ratcliffe and Mr. S. J. Shaw, of the Cavendish Laboratory, for observing that the Droitwich transmissions were unmodulated before reaching Stagshaw.

We wish to express our appreciation of the assistance and co-operation we have received from Messrs. Kirke and Wilson, and in particular from Mr. R. A. Rowden, of the Engineering Research Department of the British Broadcasting Corporation.

L. G. H. Huxley
H. G. Foster
C. C. Newton
Department of Electrical Engineering,
University of Birmingham.
Jan. 6.

[1] *Nature*, **131**, 840 (1933).
[2] *Nature*, **133**, 218 (1934); *Phil. Mag.*, **18**, 369 (1934).
[3] *Proc. Roy. Soc.*, A, **88**, 336 (1913).
[4] *Nature*, **135**, 585 (1935).
[5] *Nature*, **139**, 68 (1937); *Phil. Mag.*, vii, **23**, No. 157 (1937).
[6] *Nature*, **139**, 838 (1937).
General reference: "The Behaviour of Slow Electrons in Gases", Section 6.5, R. H. Healey and J. W. Reed (Amalgamated Wireless (Australasia), Ltd.).

Range-Energy Relation for Protons and α-Particles in the New Ilford 'Nuclear Research' Emulsions

We have recently completed an investigation to determine the relation between the energy of protons, α-particles and other light nuclei and their range in the new Ilford 'Nuclear Research' emulsions[1]. A complete account of the experiments is now in the press[2], but in view of present delays in publication and for the convenience of other workers we wish to give a short account of the results.

The method employed was to determine the mean range in the emulsion of homogeneous groups of α-particles from the natural radioactive elements, and of protons from various well-known disintegration reactions. In the latter experiments, homogeneous beams of primary deuterons of known speed were employed, and the disintegration particles were observed in conditions of good geometry. It was thus possible to calculate the energy of the groups of particles, produced by various transmutations, from the known masses of the reacting nuclei. Experiments with targets of five of the light elements bombarded with 900 keV. deuterons enabled us to determine the range in the emulsion of twelve homogeneous groups of protons, of various energies in the interval from 2 to 13 MeV., and to construct a curve showing the relation between energy and range.

It is convenient to represent the results in terms of the mean stopping power of emulsion. This quantity, S, is defined as the ratio of the mean range in standard air of a group of particles of given energy to their mean range in the emulsion. In determining S from our observations, we used the values given by Livingston and Bethe for the ranges in standard air of protons of different energy.

In Fig. 1, Curve *a* shows the average stopping power of the *B* 1 type of emulsion for protons of different range. To determine the energy of a homogeneous group of protons of mean range, r, in the emulsion, the stopping power S_r corresponding to this range is found from the curve. The corresponding range in air, R, is given by the relation $R = S \times r$, and the energy, corresponding to this value of the range in air, can be deduced from the Livingston–Bethe curves. Curve *b* shows similar results for α-particles. In this case, in addition to the groups of α-particles emitted from samarium and from some of the heavy radioactive elements, we made use of the long-range α-particle group from the reaction Li^6_3 (d,α) He^4_2.

Although our observations are confined to the *B* 1 type of the 'Nuclear Research' emulsions, we believe

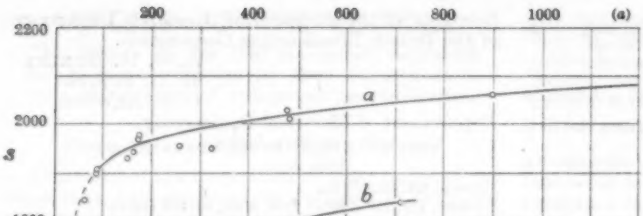


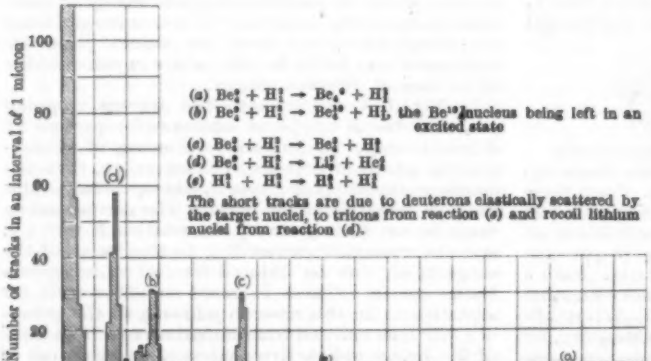
Fig. 1. O, PRESENT EXPERIMENTS; ●, GIBSON, GREEN AND LIVESEY'S EXPERIMENTS

that the atomic composition of the other types, *C* 1, *C* 2, *E* 2, etc., is so nearly equal to that of *B* 1 that the present results may be generally applied without serious error. This view is strengthened by the results of experiments by Gibson, Green and Livesey with the *C* 2 emulsion, in which the ranges of α-particles from the heavy radioactive elements were determined. Points representing their observations are included in Curve *b*, and it will be seen that they are very close to those derived from the present experiments. According to the measurements of Tsien, Chastel, Faraggi and Vigneron[3], and to our own observations on the range of the α-particles of thorium *C'*, the *A* 1 emulsion has a slightly higher stopping power for α-particles than *B* 1 or *C* 2.

We may direct attention to two other features of the method in the conditions provided by the new emulsions.

First, as an example of its 'resolving power', Fig. 2 shows the distribution in range of 2,000 tracks, produced by the disintegration particles emitted from a thin evaporated film of beryllium bombarded by 900 keV. deuterons. The reactions giving rise to the particles composing the different peaks are indicated. The 'widths' of the peaks produced by the groups of protons are only a little greater than the value to be attributed to 'straggling', finite target thickness, etc. We may conclude that the precision with which the energy of a proton can be determined from the length of the track which it produces in the emulsion is now limited only by straggling.

Secondly, the 'discriminating power' of the *B* 1 emulsion, although inferior to that of *C* 1 and *E* 1, is sufficiently great to allow us to distinguish the tracks of protons from those of α-particles of the same range. We are thus able to observe homogeneous groups of protons in the presence of α-particles, and to determine their mean range. As a result of the discriminating power of the emulsion we can show that peak (*b*) of Fig. 2 is due to protons. The mean range of the particles is such that they cannot have been produced by the disintegration of any of the light elements which might have been present as an impurity in the target. We therefore ascribe them to the reaction $Be^9_4 + H^2_1 \rightarrow Be^{10}_4 + H^1_1$, the Be^{10}_4 nuclei being formed in an excited state at 2·2 MeV.



We are indebted to Messrs. Gibson, Green and Livesey for permission to quote the results of the ranges of α-particles in the *C* 2 emulsion. We have pleasure in thanking Dr. Burcham and Mr. Livesey, who made it possible for us to obtain exposures to the beam of deuterons from the Cambridge high-tension generator.

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P. H. FOWLER
P. CUER

H. H. Wills Physical Laboratory,
University of Bristol. Jan. 2.

[1] Powell, Occhialini, Livesey and Chilton, *J. Sci. Instr.*, **23**, 102 (1946).
[2] Lattes, Fowler and Cuer, *Proc. Phys. Soc.*, in the press.
[3] Tsien, Chastel, Faraggi and Vigneron, *C.R. Acad. Sci. Paris*, **223**, 571 (1946).

Surface Formation of Lithium Negative Ions

SOME years ago, Arnot[1] directed attention to the fact that bombardment of a surface with positive ions resulted in the liberation of negative ions of the same species. Shortly afterwards, Sloane and Press[2], using a double mass spectrometer and employing magnetic sorting of both the bombarding positive ion beam and the resulting negative ions, were able to prove that bombardment of a surface by positive ions of a given kind could result in the formation of a whole spectrum of negative ions.

We have recently bombarded a nickel surface with positive ions from a lithium thermionic source, and detected two peaks in the resulting negative ion spectrum due to ions with mass-to-charge ratios of 7 and 6 in atomic units. The ratio of the 7 and 6 peak heights in the spectrum is approximately 10 to 1, which is about what would be expected for the lithium isotopes. Both peaks contain ions with energies in excess of that imparted to them by the accelerating

electric fields, a property which seems to be characteristic of negative ions produced by positive-ion bombardment of surfaces[1,2].

We also detected two negative ion peaks with mass-to-charge ratios 23 and 22, again with peak heights in approximately the ratio of the lithium isotopes. This ratio was maintained under different experimental conditions, although the relative intensities of neighbouring peaks at 24, 25 and 26 varied markedly. These observations suggest that 23 and 22 may be due to $Li_2O_{16}^-$ and $Li_2O_{16}^-$, an interesting possibility in view of the fact that 23, when reported before[3], has been attributed to Na^-. One of us (R. H. S.) and J. F. I. Cole recorded the 23 peak last year while bombarding a tantalum gauze with ions from a Kunsman sodium positive-ion source; but, because of its behaviour when experimental conditions were altered, hesitation was felt in attributing it to Na^-. It was always so small that the possible presence of 22 could not be checked.

These new results do not, of course, preclude the existence of a stable sodium negative ion; but they do appear to show that a negative ion peak at 23 can be due to a lithium compound, and that it is unwise to identify it as Na^- unless the peak due to ^{22} is simultaneously shown to be less intense than it would be if it were due to the compound containing the other lithium isotope.

In their important pioneer work on this subject K. S. Woodcock[4] and J. S. Thompson[5] bombarded surfaces with positive ions from a lithium source but did not record Li^-.

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H. M. Love

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[1] Arnot and Milligan, *Proc. Roy. Soc.*, A, **156**, 538 (1936). Arnot, *Proc. Roy. Soc.*, A, **158**, 137 (1937); *Proc. Roy. Soc.*, A, **158**, 157 (1937).
[2] Sloane, R. H., and Press, R., *Nature*, **141**, 872 (1938); *Proc. Roy. Soc.*, A, **168**, 284 (1938).
[3] Schaefer, H., and Walcher, W., *Z. Phys.*, **121**, 679 (1943).
[4] Woodcock, K. S., *Phys. Rev.*, **38**, 1696 (1931).
[5] Thompson, J. S., *Phys. Rev.*, **38**, 1389 (1931).

Uranium Not a Superconductor

It has recently been reported[1] that Justi has found uranium to become superconducting at 1·25° K. About a year ago, I looked for superconductivity in a very pure sample of uranium using the magnetic moment method. Below about 1·45° K. a slight diamagnetic effect appeared, as if about 0·5 per cent by volume of the metal had become superconducting; the critical field of this slight effect was about 210 gauss at the lowest temperature used (1·08° K.). Similar behaviour has previously been observed[2] for titanium and for a less pure sample of uranium, and it was then suggested that the slight superconducting effect is due to an impurity. The present results considered in conjunction with the chemical analysis of the sample suggest that the superconducting impurity may be uranium carbide, but I have not yet had an opportunity of testing this suggestion by direct investigation of a uranium carbide specimen.

It seems, then, that uranium is not a superconductor down to 1·08° K., and this illustrates the danger of drawing definite conclusions about possible superconductivity from resistance measurements alone (such as Justi used). A superconducting impurity, though only a small fraction of the volume, may shunt the bulk of the metal and cause the resistance to fall, but the magnetic moment provides a direct measure of the fraction which is superconducting.

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[1] Mott, N. F., *Nature*, **158**, 861 (1946).
[2] Shoenberg, D., *Proc. Camb. Phil. Soc.*, **36**, 84 (1940).

Stabilizing Linear Particle Accelerators by Means of Grid Lenses

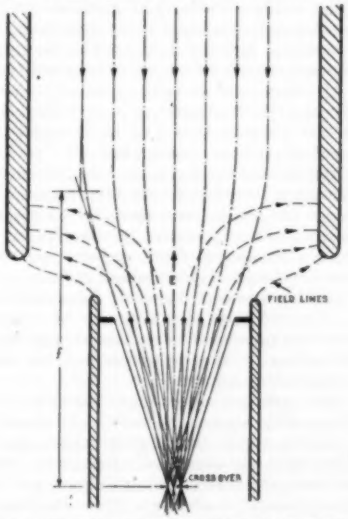
Though nothing appears to have been published, it is now fairly generally known that linear particle accelerators of the standing-wave type cannot be satisfactorily stabilized with electron lenses of conventional design for energies much exceeding about 10 MeV. I have confirmed this in an investigation starting from first principles, which showed also that lenses terminated at the exit end by a thin metal foil, such as the beryllium windows proposed by L. Alvarez of Berkeley University, promise satisfactory stability up to at least 1,000 MeV. On the suggestion of Prof. M. L. Oliphant, I extended the theory also to lenses in which the metal foil is replaced by a wire mesh grid or the like. 'Grid lenses' were investigated experimentally by Knoll and Ruska in the early days of electron optics, but they have largely fallen into oblivion. It appears now that they may well be revived for the concentration of the beam in linear accelerators, as they offer advantages equal if not superior to beryllium foils.

A gap open at one end and terminated at the other end by a conducting foil, with an electric field intensity E in the centre of the foil, acts as a condensing lens if E is accelerating. Introducing the foil produces an additional lens-power

$$\frac{1}{f} = \frac{1}{4}\frac{(1-\beta^2)^{1/2}}{\beta^2}\frac{eE}{m_0c^2},$$

where f is the focal length. As explained in the figure, this effect arises not at the foil, but by the divergence of the electric field at the other end. In the paraxial approximation it is independent of the shape of the foil.

If now the foil is replaced by a wire mesh grid or the like, with square or round holes, the beam is



Field and electron trajectories in grid lens

split up into a great number of fine pencils. In first approximation, each one of these pencils is collimated in itself; that is to say, within each mesh the lens effect produced by E is exactly compensated. But the global or macroscopic concentrating effect is by no means destroyed, as the central rays of the pencils suffer no deflexion. The effect of replacing the foil by a grid is merely that of replacing the point focus by a cross-over, which to a first approximation has the size and shape of a single grid hole. The next higher approximations (finite depth of the grid, lens effect quadratic in E, and spherical aberration) have all signs which point in a beneficial direction, that is to say, they tend to make the cross-over even smaller than a mesh hole.

With modern techniques it is possible to produce slat grids of a great variety of metals with clear areas of 98 and even 99 per cent, which can stand beam energies of several hundred watts per cm.^{2}. The danger of auto-electronic discharges starting from the sharp edges of the slats need not be very serious, as sufficient stability of operation can be obtained if the average field intensity E over the surface of the grid is only 10 per cent of the maximum or even less. Thus it appears that grid lenses may well compete with beryllium foils in the stabilization of linear accelerators for extreme energies.

I am indebted to Prof. Oliphant for his suggestion, and to the directors of the British Thomson-Houston Company for permission to publish this note.

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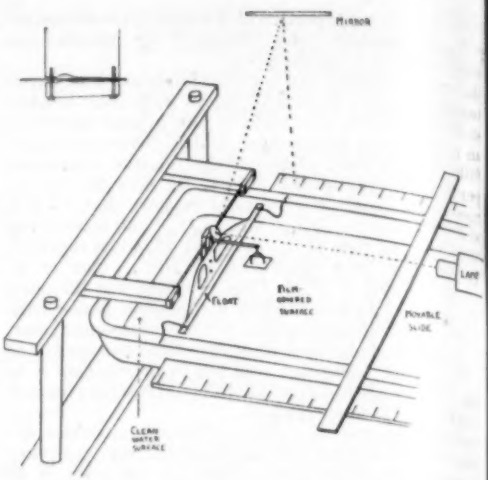
Rugby. Jan. 5.

A Simple Film Balance for Demonstration and Research Purposes

The Langmuir–Adam film balance was developed to measure the lowering of surface tension (termed the surface pressure) produced by paraffin-chain compounds such as oleic acid when spread as monolayers on aqueous solutions. With substances giving condensed films (for example, stearic acid, cetyl alcohol) the sudden lowering of surface tension when the molecules are squeezed into close-packing provides a striking lecture demonstration, and many simple experiments illustrating molecular orientation, changes of phase and physical state in two-dimensions, etc., can be demonstrated by this means. In addition, the film balance has been widely applied for research purposes, particularly to problems of colloidal systems, such as foams, emulsions, proteins and polymers; to structure determination of complex organic molecules, and recently to surface-area determination of fine powders by adsorption of long-chain polar compounds from organic solvents.

To cater for the greatly increased interest in surface chemistry, the present type of film balance was devised. In addition to simplicity of construction it has some advantages over the usual type employing a torsion balance. The principle can be seen from the accompanying figure.

The monolayer is merely compressed by the usual waxed glass slide against a relatively stout torsion wire, or better, a thin metal strip (the use of a strip is preferred as it automatically brings the float to a fixed position), and the resulting deflexion of the float amplified optically as shown. The reflecting mirror shown at the top of the figure is located by means



of a tall stand almost vertically above the far end of the torsion arm. A two-metre optical path has been found convenient for ordinary purposes. One of the horizontal scales used to indicate the position of the movable barrier also serves to measure the optical deflexions and hence the force on the float. Errors in film area due to the movement of the float are usually negligible (they can be allowed for if necessary), since this movement is deliberately kept very small. With a distance of 2 cm. between the torsion wire (strip) and the float, 1 mm. movement corresponds to 20 cm. deflexion at 2 metres. The torsion wire or strip is suitably chosen so that the float movement does not exceed *c.* 1 mm. for the maximum surface pressures encountered. Thin steel watch spring has been found very suitable for the usual film pressures, that is, of the order 10–50 dynes/cm. The torsion wire or strip can readily be changed merely by loosening the simple clips at its ends, and no difficulty in tightening it sufficiently has so far been encountered, but if necessary the device shown inset can be used.

The float consists of thin duralumin (or other metal) sheet, turned up at the edge and screwed to the vertical duralumin bar to which the torsion wire or strip is clamped. For research purposes a thin mica strip is attached by wax beneath the float to keep all metal out of contact with the solution. A rectangular 'Pyrex' baking-dish, or the glass dish used in 'Frigidaire' refrigerators, provides an excellent trough after the bevelled edges have been ground flat.

Calibration can be carried out in the usual way by adding weights to the small pan (a light wire ring and piece of paper) shown in the figure, or by spreading 'piston oils', such as castor oil or oleic acid, which give known surface pressures.

This apparatus appears to give an accuracy fully equal to that of the usual torsion balance, with the additional advantage that measurements can be carried out much more rapidly. It can also be used for automatic recording of force-area curves, and in addition can readily be adapted to measure surface or interfacial tensions.

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Reflectivity of Steel

THE method briefly described in these columns[1] some time ago was employed in an investigation of the reflectivity of two kinds of steel at different temperatures. The two specimens were 'stainless' steel, and no special precautions were taken to ensure an oxide-free atmosphere. Their composition was as follows: *SF*11, 13 per cent chromium; *SF*20, 18 per cent chromium, 8 per cent nickel. The measurements were carried out for two wave-lengths, 0·55 and 0·65 μ, and extended over a range of more than 300° C. The room-temperature results are listed in Table 1.

TABLE 1. REFLECTIVITY IN %

λ	0·55μ	0·65μ
*SF*11	50·1	54·5
*SF*20	64·8	66·4

Those for *SF*20 belong to the highest found in the literature, being in fair agreement with the values obtained by Pfestorf[2] (on Krupp *V*2*a* Edelstahl). Generally, it is impossible to carry out any comparisons, since few authors give adequate data on the composition of their specimens. The temptation to ascribe the higher reflectivity of *SF*20 to its nickel content must be resisted: in some comprehensive work which covered the visible and ultra-violet parts of the spectrum, von Fragstein[3] has found it impossible to detect any systematic variation in the reflectivity with the composition of his steel specimens. Such a variation is only likely to be found in the far infra-red.

The temperature coefficient of reflectivity is defined by

$$\alpha_\lambda = \frac{1}{R_\lambda} \cdot \frac{dR_\lambda}{dT}.$$

The values obtained in the present investigation and given in Table 2 refer to room-temperature. Since dR/dT is less dependent on the manner in which the mirror has been prepared than α, the values for the gradient proper are also presented.

TABLE 2

	0·55 μ		0·65 μ	
	dR/dT	α	dR/dT	α
*SF*11	$+1{\cdot}43\times10^{-3}$	$+2{\cdot}8\times10^{-4}$	0	0
*SF*20	$+3{\cdot}75\times10^{-3}$	$+5{\cdot}78\times10^{-4}$	$+7{\cdot}5\times10^{-3}$	$+1{\cdot}13\times10^{-4}$

As might have been expected, the mirrors tarnished when high temperatures were employed. It was interesting to observe that the reflectivity on the short wave-length side of the spectrum decreased before that near the red end. A comparison with the work of Banning[4] and Sabine[5] shows that, in the case of aluminium, the ultra-violet reflectivity is greater for the specimen which had not been exposed to air before measurements were taken. Since the reflectivities of pure aluminium and its oxide are practically the same in the visible region, it is possible to assume that the oxide layer formed by the atmosphere on the aluminium is extremely thin. This has been accounted for theoretically by Mott[6]. It would then appear that the thickness of the film in the case of steel is such as to reduce the reflectivity in a manner analogous to that of aluminium, except that the diminution occurs in the visible region. It is likely that such a film is only a transitional phenomenon for, when the mirror was heated to a temperature of more than 500° C., it turned blue. It is assumed that the predominant reflectivity of the red in the early stages is due to the film being opaque to wave-lengths shorter than these, and that the blue appearance later is due to interference phenomena in the thicker film itself.

Lastly, it is seen that $\alpha_{0\cdot65\mu} = 0$ for *SF*11. Such a point has been termed an X-point by Price[7], and is said to be characteristic of each metal. While its significance from the point of view of pyrometry cannot be over-estimated, especially if this coefficient should be zero over large temperature ranges, it is not thought that it has any fundamental value. Its existence can be predicted at least qualitatively on the basis of classical electro-magnetic and electronic theory. A complete analysis of this fact will be given on another occasion.

The above work has been carried out under the auspices of the Pyrometry Sub-Committee of the British Iron and Steel Research Association. I am indebted to the Committee for permission to publish this account, and to Mr. W. C. Heselwood, of the United Steel Companies, Ltd., Sheffield, for the supply of the specimens.

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Jan. 2.

[1] Weil, *Nature*, **158**, 672 (1946).
[2] Pfestorf, *Ann. Phys.*, **81**, 906 (1926).
[3] v. Fragstein, *Ann. Phys.*, **17**, 1 (1933).
[4] Banning, *J. Opt. Soc. Amer.*, **32**, 98 (1942).
[5] Sabine, *Phys. Rev.*, **55**, 1064 (1939).
[6] Mott, *Trans. Farad. Soc.*, **35**, 1175 (1939).
[7] Price, *Proc. Phys. Soc.*, in the press.

Choice of a 'Reality Index' for Suspected Cyclic Variations

IN *Nature* of December 21, Dr. W. Gleissberg proposes an index R for estimating the reality of cyclic variations in a series of observations. This index involves the average length L of a 'run' and the standard deviation S, about this mean, as calculated by Kermack and McKendrick[1]. The object of this communication is not to discuss the arguments for or against the proposed index, but to point out an error of a somewhat subtle type which occurs in the example given by Dr. Gleissberg. Figures are given representing the heights of sunspot maxima for 18 consecutive periods. The mean length of the runs, L, is 2·4, which is very close to the theoretical mean, 2·5. Consequently the reality index, $R = D^2/D^2+S^2$, where $D = L - 2{\cdot}5$, is small. So far as this test goes, the fluctuations may well be random ones and not dependent on 'real' cyclic variations.

In order to eliminate accidental or experimental errors, Dr. Gleissberg proceeds to take running averages of the observations in groups of four, the first group consisting of the first four observations *a*, *b*, *c* and *d*, the second of *b*, *c*, *d* and *e*, the third of *c*, *d*, *e* and *f*, and so on. In this way he obtains fifteen averages each of four observations, and goes on to calculate the value of the reality index R for this derived set. The mean length L is found to be 3·8, which exceeds 2·5 by 1·3, a quantity very large in comparison with the standard deviation, and R comes out very nearly unity.

A little consideration shows that this calculation is quite inappropriate for a series derived, as above, by forming running averages. The mean length of a 'run' L is 2·5 in an infinite series, $n_1, n_2 \ldots, n_x \ldots,$

of, say, random decimals between 0 and 1. But the numbers derived from such a random series by taking running averages of groups of t or, what for present purposes is essentially equivalent, taking the sums

$$\sum_{x=1}^{t} n_x, \quad \sum_{x=2}^{+1} n_x, \quad \ldots \quad \sum_{x=m}^{t+m-1} n_x,$$

no longer form a random series, and the average length of a 'run' is no longer 2·5. It is not difficult, in fact, to show that, whatever t may be, the average length of a 'run' is 3·0, except in the special case when $t = 1$. The following does not claim to be strictly rigorous.

First take the exceptional case $t = 1$. Any number in a series of random numbers is a 'maximum' when it is greater than the preceding and succeeding numbers. But by hypothesis these are three numbers taken at random, and the probability that of three such numbers the middle one should be the greatest is clearly $\frac{1}{3}$. Thus the probability that any number in the series should be a 'maximum' is $\frac{1}{3}$. Similarly, the probability that any number should be a 'minimum' is also one third. If we have a long series containing N numbers, there will be approximately $2N/3$ 'extrema' ('maxima' and 'minima'), and it follows at once that the average length of a 'run' is 2·5, the length as explained in Dr. Gleissberg's letter being the number of numbers in the 'run', including the first and the last.

Let us now take $t = 4$; it is easily seen that the argument holds when $t \geqslant 2$. If the original series is $a, b, c, d, e, f, \ldots$, the derived series is $(a+b+c+d)$, $(b+c+d+e)$, $(c+d+e+f)$ . . . Clearly the middle term will be a 'maximum' provided e is greater than a and b is greater than f. But there is a probability of each of these conditions being fulfilled of $\frac{1}{2}$, and the two events are independent as the original series is a random one, and so the probability of the two events occurring together is $\frac{1}{4}$. Thus in the derived series one quarter, and not one third, of all the numbers are 'maxima', and one quarter are similarly 'minima'; one half of all the numbers are 'extrema'. It readily follows that the average length of a 'run' is now 3 and not 2·5. The standard deviation of the lengths of 'runs' about the mean length would presumably differ from the special case where $t = 1$, but its calculation would be more involved.

To test these results, the first two hundred of Fisher and Yates' random numbers were taken from their tables (Statistical Tables for Biological, Agricultural and Medical Research). These numbers each contained only two digits and this means in effect that we are limited to a hundred different numbers instead of an infinite population. However, the deviation from the theory occasioned by this limitation is but slight. Where two consecutive numbers are equal, they were counted as one 'extremum'.

It was found that the series of two hundred numbers contained 129 'extrema'. Taking $t = 2$, that is, the series $(a+b)$, $(b+c)$, $(c+d)$ . . ., etc., the number of 'extrema' was 96. Taking $t = 4$, that is, the series $(a+b+c+d)$, $(b+c+d+e)$ . . ., etc., the number of 'extrema' was 94. These results may be compared with the expected values of $\frac{2}{3}(200-2) = 132$ in the case of the series of two hundred numbers (the first and last of the two hundred numbers are excluded in the calculation as they cannot figure in 'extrema'), 98·5 in the case of $t = 2$ and 97·5 in the case of $t = 4$. Clearly, for $t = 2$ and $t = 4$, the number of 'extrema' found agrees closely with that required by the above theory, but differs considerably from what would be expected in a really random series.

The above considerations do not disprove Dr. Gleissberg's final conclusion that there is an underlying cyclic variation in the sunspot maxima, obscured by some random effects; but they do suggest that this particular application of his reality index is not rigorously sound. If this, or any similar index, meets with general acceptance, it is important that the conditions under which it can be applied should be adhered to.

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Dec. 31.

[1] *Proc. Roy. Soc. Edin.*, **57**, 228 (1936).

Spiral Cracks in Glass Tubes

I BELIEVE that the interesting experiments recently reported in *Nature*[1] cannot, for symmetry reasons, be explained on the ordinary theory of strength of homogeneous materials; but an attempt at a qualitative study of the spiral cracks according to Griffith's views on the phenomena of rupture[2] may be developed as follows.

If we assume that at normal temperature 'Pyrex' glass possesses some kind of porosity with a random distribution of small spherical cavities, the surface tensions acting along these inner boundaries oppose themselves to thermal dilatation and, consequently, in heated glass, many spherical cavities will be deformed into ellipsoids. Both eccentricity and stress concentration at the ends of the major axis will increase with temperature.

As in rapid breakings the hypothesis of fracture propagation in the direction of maximum strain seems quite admissible, we have to calculate the most unfavourable orientation of the major axes of the cavities from which the cracks will start. To a first approximation, we can consider a plane plate with elliptic holes of given average eccentricity undergoing a tensile stress, and keep the deductions valid for the external layer of the annealed tubes.

Denote by φ the angle between the direction of stress S (at infinity) and the major axis of the hole; then the extension L of the axis can be expressed in the well-known form: $L = S(A\cos^2\varphi + B\sin^2\varphi + 2C\sin\varphi\cos\varphi)$, where A, B are coefficients of elasticity for tensile stresses parallel to the axes of the ellipse, and C (the value of which is not strongly influenced by eccentricity) is the analogous coefficient for a pure shearing stress.

L is a maximum in the directions determined by the equation: $tg2\varphi = 2C/|(B - A)|$.

Now, the difference $|(B - A)|$ depends upon eccentricity and increases with temperature: hence φ and the helix pitch decrease; moreover, L, too, increases with temperature, and so does its derivative with respect to φ; $L_{max.}$ is more sharply defined, and this explains why at high temperature the cracks are more regular; their finer structure may be caused by the rapidity of formation, as for dynamical compression tests on paraffin at normal temperature[3].

At still higher temperature, φ becomes very small and possibly less than the limits determining the phenomenon; in this case the crack is closed and we have segmentation.

Finally, at low temperature, φ should approach 45°; but during the same time, the variations of L with respect to φ greatly diminish, rupture is no

longer very rapid and it occurs statically (along a generatrix) rather than dynamically (at 45°); so we only have straight or steep wavy lines.

LIVIO NORZI

C.so Gal. Ferraris 90,
Torino.
Dec. 16.

[1] *Nature*, **158**, 582 (1946).
[2] Griffith, A. A., *Phil. Trans. Roy. Soc.*, **221**, 163 (1921).
[3] Cf. Nadal, "Plasticity" (McGraw-Hill, 1931), 111.

Electrogenic Properties of Acetylcholine

FOLLOWING the classical work of Dale on acetylcholine, numerous investigators have demonstrated the important part played by this quaternary amine in the nervous system[1]. A neglected property of acetylcholine is its extraordinary electrogenic action at the phase boundary between oils and aqueous solutions[2]. This negative phase boundary potential provides a possible explanation of the electrical component of the nerve impulse in cholinergic nerves[3]. It seems reasonable to suppose that the action potential[4] might arise from the contact of acetylcholine with the lipoid layer of the nerve fibre according to the theory of phase-boundary potentials[5]. Moreover, it has been shown that acetylcholine produces a negative electrical potential on living frog skin[6].

The penetration of acetylcholine into an oil layer can be determined by measurements of the fall in resistance of oil in contact with solutions of acetylcholine in physiological saline. For E.M.F. studies, equal parts of cholesterol are added to the oil, but for conductivity measurements more uniform results are obtained with a pure solvent. Guaiacol[7] has several properties found in protoplasm, such as its conductivity, and the property of distinguishing between potassium and sodium and, above all, absorbing lipoid-soluble substances. 20 c.c. samples of guaiacol were shaken for five hours with 100 c.c. samples of the aqueous solutions. In a typical experiment (at 25° C.) the oil had a specific resistance of 140×10^4 ohms after shaking with saline; 25×10^4 ohms after shaking with 50 mgm. per cent acetylcholine in saline; 19×10^4 ohms after shaking with 100 mgm. per cent acetylcholine in saline; 10×10^4 ohms after shaking with 200 mgm. per cent acetylcholine in saline.

The measured phase-boundary potential of 50 mgm. per cent acetylcholine in saline in contact with guaiacol was 35 mV. (negativity), which is close to the value of 45 mV. calculated from the above data. According to the Nernst equation, the potential can be calculated as the logarithm of the difference in concentration of the common ion (difference in conductivity of oil in contact with sodium chloride and in contact with acetylcholine chloride—a seven-fold difference) multiplied by the factor 0·058 for room temperature.

The fall in resistance of nerve during activity might be explained as the fall in resistance of the nerve lipoid layer produced by the penetration of acetylcholine. There is no longer need to postulate the breakdown of an imaginary Bernstein membrane[8].

If an electroencephalograph is employed instead of the usual potentiometer to measure the electrical change produced by adding acetylcholine to an oil layer, it is found that the negativity rises very rapidly, resembling the upstroke of the spike potential in nerve. The downstroke of the spike potential in nerve might be produced by the acetylcholine reaching the opposite side of the extremely thin oil layer at the surface of the nerve fibre. There is also the possibility that the enzyme choline esterase[9] destroys the acetylcholine potential, thus forming the downstroke of the spike potential in nerve. Acetylcholine solutions were shaken with esterase preparations and the potentials measured at an oil boundary. In a typical experiment, two 200 c.c. samples of saline containing 50 mgm. per cent acetylcholine with 100 mgm. per cent bicarbonate and 6 gm. of minced fresh cat brain (cortex) gave phase boundary potentials of 7 and 3 mV. negative in contact with 10 per cent cholesterol in guaiacol, compared with 32 and 29 mV. negative given by two control solutions of identical composition but containing no brain substance. 200 c.c. of saline with 100 mgm. per cent bicarbonate but no acetylcholine or brain and shaken for the same time (5 hr.) gave a potential of 7 mV. positive. 1 mgm. per cent eserine and also 0·05 per cent di-isopropyl fluorophosphate preserved the electrogenic properties of acetylcholine solutions in the presence of esterase; but other workers[10] have found that these anti-esterase agents fail to prolong the spike potential in nerve, showing that esterase is not essential for the formation of the electrical nerve impulse. In living cholinergic nerve, esterase probably has a minor function of removing excess acetylcholine.

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Partition-Chromatography and Living Cells

CHROMATOGRAPHY appears likely to play an important part in future work on protein analysis. The partition method[1,2], whereby amino-acids can be separated and identified on a cellulose strip, is sensitive to extremely small amounts of material. For example, 1 μgm. of an amino-acid gives a clearly visible colour reaction with ninhydrin. The method may ultimately, therefore, prove valuable for the protein analysis of the chromosomes and their products. With suitable solvents and developers, it should be possible to separate and determine the nucleic acids, as well as amino-acids. In our preliminary experiments, the method has been used to survey the presence of free amino-acids in plant and animal tissues at different stages of nuclear activity.

The following tissues have been tested: salivary glands of *Drosophila*, root tips of *Trillium*, anthers of *Tradescantia* at various stages of meiosis and pollen formation, and the white and yolk of a hen's egg.

Small amounts of the tissues and separated egg were smeared direct on to filter-paper strips; the crushed root tips being attached by means of a starch support. As a check on the possibility of protein degradation after death, a duplicate smear of each cell type was fixed by dooding with ethyl alcohol; but no difference in results was found. The paper strips were run in one dimension only, using water-saturated phenol as the solvent. The air-tight chamber in which separations were carried out contained a two-phase solution of water and phenol at the bottom. After 24 hours treatment, the filter-paper strips were dried in a water-oven at 98° C., sprayed with ninhydrin and dried again in the oven to allow the colour spots to develop. Only two kinds of result were obtained: (1) no coloration (that is, no free amino-acids): salivary glands and white of egg; (2) two or more colour bands indicating the presence of two or more free amino-acids: all the plant cells and yolk of egg.

The nature and exact location of the free amino-acids is at the moment a matter for speculation. Previous work by the use of other methods has already shown them to be present in plant tissues[3]. Whether their absence in salivary glands can be attributed to the absence of mitosis remains to be shown.

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Metabolism of Fatty Livers

Earlier work on the metabolism of fatty livers by Ennor[1] showed that the oxygen consumption and the acetoacetic acid production of liver slices from guinea pigs poisoned with carbon tetrachloride is considerably in excess of normal. Since adenosinetriphosphate is essential for the oxidation of fatty acids[2], it was considered of interest to determine a possible correlation between high-energy phosphate content and the increased metabolism of such livers.

0·1 ml. of carbon tetrachloride in arachis oil was given by subcutaneous injection to well-fed guinea pigs of approximately 300 gm. body-weight. Two to four doses were given at 24–48 hour intervals, and both control and treated animals were starved for 24 hours before killing. The major portion of the liver was dropped into liquid air within 30 sec. of the death of the animal; the remainder of the liver was taken for fat, nitrogen and total phosphorus determinations. Duplicate samples of the powdered, frozen liver were extracted twice with trichloracetic acid and, after removal of the protein, aliquots were taken for an analysis of the barium-insoluble fraction precipitable at *p*H 8·2. Determinations were made of the inorganic phosphorus originally present and that released on heating at 100° C. in *N* sulphuric acid for varying time intervals up to three hours. All figures are calculated on the basis of the nitrogen content of the original liver.

From the accompanying table it will be seen that the readily hydrolysable phosphorus (7 min.) is higher in the livers of the treated animals than in the control series. The relative amounts of adenosine

Controls			Treated		
No. of expt.	N gm. %	mgm. % P on 7 min. hyd.	No. of expt.	N gm. %	mgm. % P on 7 min. hyd.
34	3·89	1·2	35	2·15	4·5
37	3·58	1·7	38	2·53	2·1
39	3·63	1·1	47	1·85	3·7
52	3·25	1·0	53	1·84	3·3
56	3·51	1·6	57	2·20	2·8

di- and tri-phosphates present in this fraction have not been fully established; but it is of interest that the increase, due primarily to the presence of these compounds, is associated with the increase in metabolism found in fatty livers of this type.

A full report of this work will appear elsewhere.

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Mechanism of the Action of X-Rays on Enzymes in Water-Solution

It is a well-established fact[1] that the action of ionizing rays on substances dissolved in water often proceeds in a way suggesting an interaction of some irradiation products of the water molecules. As regards the nature of these hypothetical intermediary products and the mechanism of the action on the dissolved substances, Weiss[2] has discussed the possible formation of H-atoms and OH-radicals. The biological significance of the reactions has also been tentatively discussed. If a second component is added, the action of X-rays on the substance under consideration may change owing to dissipation of the primary X-ray products between the two substances.

Some experiments may further elucidate the mechanism. The X-ray dose given was 12·400 r., the intensity 275 r./m. The enzyme studied here was pure crystalline catalase[3] diluted to a concentration of $3{\cdot}7 \times 10^{-6}$ gm./ml. The experiments were run at *p*H 7·4 and in an atmosphere of nitrogen in order to avoid the interaction of gaseous oxygen; 6–12 tests were used for each substance (see accompanying table).

Substance added (conc. 0·1–0·2 m*M*.)	Inactivation (per cent)
Enzyme alone	53·9 ± 1·4
Maleic (fumaric) acid	30·9 ± 3·2
Malonic acid	54·3 ± 2·1
Succinic acid	53·1 ± 0·9
Pyruvic acid	40·8 ± 1·7
Lævulinic acid	46·3 ± 3·6
Glutathione	71·0 ± 3·7
Oxidized glutathione	30·2 ± 1·3
Cysteine	67·5 ± 7·4
Cystine	28·6 ± 1·4

Unsaturated substances, which may be expected to react with the water products (for example, fumaric and maleic acids), act as protective systems. Related saturated acids (malonic and succinic acids) show no signs of influence, whereas ketocarbonic acids, for example, pyruvic and lævulinic acids, are protective (the latter in a less pronounced manner).

Some of the other experiments reported in the table are more instructive as to the mechanism of the

reaction. Glutathione (cysteine) increases, whereas oxidized glutathione (cystine) decreases the action of X-rays; for this we suggest the following explanation. Suppose the water is primarily split into H-atoms and OH-radicals. In the presence of glutathione (or cysteine) the reaction $2\,RSH + OH \rightarrow 2\,RSSR + H_2O + H$ may occur to some extent, thus increasing the chances of a reaction between the enzyme and the H-atoms. In the presence of the oxidized product, the reverse takes place. According to this conception the action will *in this instance* be exerted by free H-atoms. The protection of the ketocarbonic acids may then be considered to depend on a reduction of these substances. Another X-ray reaction may be mentioned in this connexion. Fricke[4] has shown that pure water is not measurably decomposed by X-rays, but it is in the presence of small amounts of iodine ions (1·0–0·01 millimol.). Formation of hydrogen peroxide, and in unbuffered or alkaline solution also oxygen, that is, oxidizing products, can be proved. It is conceivable that the presence of iodine ions will decrease the amount of free hydrogen atoms. Now the addition of such quantities of iodine ions affords a very strong protection for the catalase against the X-rays, so that doses up to ten times as big must be given in order to obtain the same effect as without the iodine ions.

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Action of Light upon Jute

The treatment of jute with certain alkylating and acylating agents inhibits the discoloration which this fibre, in common with most ligno-cellulosic fibres, undergoes on exposure to light[1,2].

One approach to a better understanding of the factors involved in the discoloration and in its prevention is afforded by a study of the chemical reactions which take place on irradiation. Samples of jute yarn and powder have been exposed to the light of a quartz mercury-vapour lamp; the yellow-brown colour produced is the result of two or more reactions leading to the formation of yellow and brown reaction products. A large part of these derivatives is soluble in water, and the yellow to brown colour of the solution is intensified on addition of alkali but reduced by the action of sulphur dioxide. It is clear that the soluble, coloured reaction products are of relatively small molecular weight and that they are derived mainly from the ligneous encrusting materials, though degradation products of the hemicellulosic constituents may also be involved. Irradiation leads to a reduction in the yield of lignin-forming units and a reduced yield of furfuraldehyde. Furthermore, the methoxyl content of lignin isolated from irradiated jute is lower than that of the comparable fraction from a non-irradiated sample. Demethoxylation of the lignin-forming units to polyhydroxy phenolic fission products, which are converted to quininoid forms, and the formation of furfural polymers or furfural-phenol condensation compounds, are held to be the sources of the coloured derivatives.

The formation of these coloured compounds can be prevented either by removal of the lignin or by acetylation. Methylation with an ethereal solution of diazomethane only partially inhibits the reactions. Irradiation of an acetylated sample results in a loss of acetyl groups, the major portion of which can be recovered as free acetic acid, though the presence of a small amount of bound acetic acid, liberated after hydrolysis with potash, has been noted. It is concluded that irradiation of acetylated and methylated jute produces substituted polyhydroxy phenols which are incapable of forming coloured quinones. The bleaching of acetylated jute, which occurs on irradiation, is not observed with methylated jute. This is probably due to the labile acetyl groups forming a bleaching agent such as acetyl peroxide, which has been shown to bring about the bleaching of acetylated jute. Acetylation, as an aid to colour inhibition, appears, therefore, to have the two functions of preventing quinone formation and causing the production of a bleaching agent during irradiation.

I wish to thank the Indian Jute Mills Association Research Institute for permission to publish this note.

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Artificial 'Breaking' of the Diapause in *Drosophila nitens*

Laboratory strains of *Drosophila nitens* Buzzati-T., though kept under constant conditions of temperature and lighting, are known[1] to undergo a winter diapause (November–March) at the imago stage. A few individuals reproduce in winter, but at a very slow rate. This was a handicap to genetical studies on this species.

It is known that various external stimuli may 'break' the diapause of the insects, although the mechanism of their action is not completely understood[2]. Our experiments showed that individuals of *Drosophila nitens* exposed to low temperature (ten days at 2–5° C.) one month from the beginning of the diapause, after which they were kept again at 25° C., are induced to 'break' the diapause and reproduce actively. Egg-laying is high; the larvæ develop at a normal rate; the adults emerged reproduce again, as if the winter period had been overcome.

From an ecological and physiological point of view, it will be interesting to see when the treated strains will undergo the diapause again, since their reproductive period began precociously: that datum will be of importance in seeking causes of the seasonal cycle of the species.

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A CONTINUUM THEORY OF RHEOLOGICAL PHENOMENA

By Dr. K. WEISSENBERG

WHEN materials of different kinds are subjected to mechanical actions we may observe a great variety of rheological phenomena, and we shall confine our attention here to a certain group of them which allows a theoretical and experimental investigation on a macroscopic scale. Here then, as in the classical theories of elasticity and hydrodynamics, we can treat the materials as continuous media, and the forces and displacements as vectors which vary continuously in space and time.

Let us consider first what happens in an appropriately chosen cycle of rheological states. We start with a material in a *ground-state*, that is, in a state in which every portion is at rest and free from external forces. We then impose some mechanical action and thereby bring the material into the particular *energized* state the phenomena of which we want to investigate. Finally, to complete the cycle, we suddenly release all external forces and allow the material to drift back into some ground-state (which may or may not be the one from which it was started). We can now define as a characteristic parameter of the energized state considered, and of the phenomena produced therein, the *recoverable strain*, that is, the amount of strain recovered after the release of the forces.

An experimental investigation was carried out under Dr. C. H. Lander[1], and in this we found it convenient to classify a material as *stable* if it regains always the same mechanical properties after completing a cycle from one ground-state to another, and to refer to it as *general* or *special* in some range of rheological states, according as the recoverable strain reaches in that range finite values, or remains infinitesimally small or zero throughout. The investigation covered a wide range of stable materials comprising such solids and liquids as are homogeneous and isotropic in all their ground-states. It revealed the differences in behaviour between general and special materials rather strikingly under certain conditions, as is illustrated in Fig. 1 for liquids, that is, for materials which flow under any shearing stress, however small.

The experimental arrangement is such that the liquid is sheared in a gap between an outer vessel rotated with an angular velocity that is kept constant at various levels, and an inner member which is held against rotation and either rigidly fixed in position or free to move up and down the axis of rotation. The conditions are so chosen that under the combined actions of the shear imposed at the boundaries, and the forces of gravity and inertia (centrifugal forces), the liquid executes a stationary laminar shearing movement.

An analysis of the experimental results shows that in such a motion the stress has its strength so distributed over the various directions in space as to comprise, in addition to the shear stress components, a pull along the lines of flow. We obtained direct experimental evidence for the presence or absence of such a pull by suddenly stopping the motion, and then making cuts perpendicular to the lines of flow. The general liquid used had a time of relaxation sufficiently long for the stress to persist appreciably after the stoppage, and the pull component present in this stress caused the cuts to open up. This pull

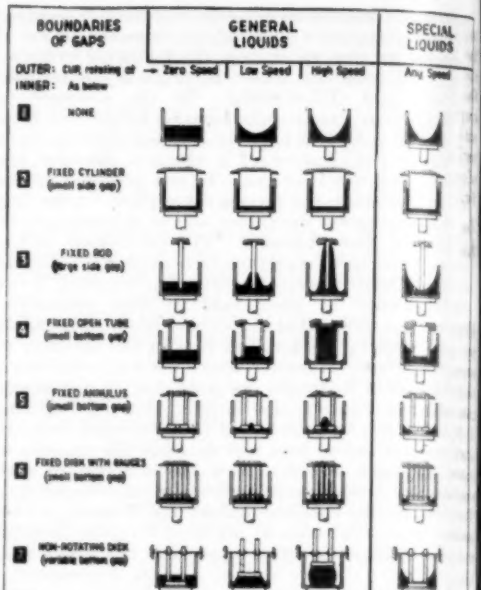
BOUNDARIES OF GAPS
GENERAL LIQUIDS
SPECIAL LIQUIDS
OUTER: Cup rotating at
INNER: As below
Zero Speed
Low Speed
High Speed
Any Speed
1 NONE
2 FIXED CYLINDER (small side gap)
3 FIXED ROD (large side gap)
4 FIXED OPEN TUBE (small bottom gap)
5 FIXED ANNULUS (small bottom gap)
6 FIXED DISK WITH BAUGES (small bottom gap)
7 NON-ROTATING DISK (variable bottom gap)
MAXIMUM SHEAR STRAIN RECOVERY IN GIVEN RANGE OF CONDITIONS
GENERAL (any finite value)
SPECIAL (infinitely small value)

Fig. 1. Flow of liquids under actions of stationary shear in gaps

distinguishes the general liquids from the special ones, being of finite amount or infinitesimally small when the recoverable strain is finite or infinitesimal. (Liquids which are in a certain range 'general' must in the same range be 'non-Newtonian' or 'anomalous'; while liquids which are 'special' may be 'Newtonian' or 'normal', but need not be so.) If, as in our experiments, the lines of flow are closed circles, the pull along these lines strangulates the liquid and forces it inwards against the centrifugal forces and upwards against the forces of gravity. The presence and absence of such a strangulation is illustrated in Fig. 1 under the column divisions headed respectively "General Liquids" and "Special Liquids".

I am greatly indebted to Dr. Lander and to his collaborators, Dr. P. Rosin, Dr. H. Fehling, Mr. M. Deutsch and Mr. R. J. Russell[2], for the generous help they gave me in these experiments, and to Mr. S. M. Freeman for many improvements in the experimental technique. My thanks are also due to Dr. F. H. Garner and Dr. A. H. Nissan who, on being informed of the results obtained and while continuing their own lines of research[3], suggested a useful arrangement of pressure gauges (see Fig. 1, row 6).

A continuum theory was developed for the rheological states of general and special materials, along the lines of the classical treatment of elastic continua. As a first approximation a theory was proposed[4], containing an arbitrarily assumed law of elasticity, and from this theory predictions were made for a pull along the lines of flow and for a great variety of rheological phenomena, including such as are reproduced in Fig. 1. The experimental investigation under Dr. Lander (1943–45) then revealed that in a variety of materials, including saponified oils, solutions of rubber, starch, cellulose acetate, etc., the predicted phenomena actually

occur, but with a systematic discrepancy between the strength of the stress components anticipated in the various directions of space and that actually found in quantitative measurements. The discrepancy was rectified, and full agreement reached with all experimental results obtained so far, in a revised theory, in which the arbitrarily assumed law of elasticity was replaced by an empirical law of the form

$$\frac{P_{au} - P_{bv}}{R_{au} - R_{be}} = \frac{P_{bv} - P_{cw}}{R_{bv} - R_{ew}} = \frac{P_{cw} - P_{au}}{R_{cw} - R_{au}} = G(P, R) \quad (1)$$

Here—for the energized state considered—we denote by P_{kl} the kl component of stress, by R_{mn} the mn component of the recoverable strain, measured on the classical scale as the elongation ratio squared minus unity, by a, b, c and u, v, w the numbers 1, 2, 3 or any cyclical permutation of these numbers, and by $G(P, R)$ a function of the three fundamental scalar invariants of stress and strain, and other scalar parameters such as temperature, time, etc. The function $G(P, R)$ may be regarded as a generalized modulus of elasticity, the value of which may vary with the material and the rheological state, the temperature, time, etc. This is best seen when the empirical law (1) is specialized for the case of a stationary laminar shearing movement, where the suffixes 1, 2 and 3 correspond respectively to the directions of the lines of flow, the perpendicular to the shearing plane, and the normal to both these directions, and where the recoverable strain has components R_{mn} which are all zero, except R_{11}, R_{12}, and R_{21}, with $R_{11} = (R_{12})^2 = (R_{21})^2$.

Recently, further progress was made[3] when we succeeded in replacing the empirical law of elasticity (1) by a simple theoretical assumption. We consider an elastic continuum in any energized state, and imagine it cut into two parts by a plane drawn in any direction through some arbitrarily selected point. For every such plane the traction force will define a triad of mutually perpendicular directions, according to its normal, tangential and cross-components; and a second triad is defined by taking similar components of the displacement of the two parts relative to one another when the continuum recovers to a ground-state. We can formally deduce equation (1) from the assumption of a coincidence of these two triads of directions for every plane. This assumption, and the elasticity law derived from it, have been confirmed empirically over wide ranges of materials and mechanical actions; but further experimental investigations are required, and are in fact under way, to ascertain the exact limitations of validity, since a theoretical proof can be given only under certain conditions. Keeping within the range of elastic continua which are isotropic in all the ground-states, we can prove the validity of the assumption (*a*) in all classes of rheological states for certain orientations of planes, and (*b*) for all possible orientations of planes in certain classes of rheological states, including all classes restricted either to infinitesimal small strains, or to any stresses and strains with cylindrical symmetry.

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EMERGENCY SCIENTIFIC RESEARCH BUREAU, EIRE

THE report of the Emergency Scientific Research Bureau, Eire, covering the period February 21, 1941–March 31, 1945*, which was set up with Prof. J. J. Dowling as chairman, gives brief details of the work of the Bureau.

A large part of the Bureau's experimental work dealt with fuel problems, and the most important of these included the manufacture of charcoal from turf, the efficiency of mobile producer plants, and the production of town gas under emergency conditions. Work on the production of turf charcoal led to the design, erection and operation by the Turf Development Board, Ltd., of a plant on the Turraun Bog, from which charcoal suitable for use as a producer fuel was obtained with an output of up to 22 tons a week. Work on town gas resulted in a study of the possibilities of using mixtures of turf and coal, and in modifications in plant which to some extent eased the difficulties being experienced at one of the large gas works. One of the first problems studied was that of mobile gas producers, including the use of an electric filter for the gas; but although such a filter can be constructed, it is not much more efficient, is more expensive and requires much more careful servicing. The drying of turf and the development of a gas specific gravity meter were other investigations in the same field.

Much attention was given to chemicals for the manufacture of matches, including the manufacture both of phosphorus and of potassium chlorate; while a process was also worked out for the manufacture of sulphur by dry distillation from spent oxide. Plant was also developed for the supply of compressed carbon dioxide and ammonia for refrigeration purposes, for aluminium sulphate for water purification and paper manufacture, and for the manufacture of formalin by oxidation of methyl alcohol.

A geophysical survey of mineral deposits of economic importance, and the increase in output to 20 kW. of the existing 1·5 kW. short-wave Marconi transmitter at Moydrum were other tasks undertaken.

The maintenance of such essential medical supplies as anæsthetic ether, glycerol, insulin, and vitamins, and of supplies of yeast and flour for breadmaking, and the manufacture of citric acid by fermentation were other subjects investigated.

Experimental work was also carried out on the production of carbon black by combustion of used lubricating oil, the spectrographic analysis of steel, production of ferro-silicon, electro-deposition of ductile pure iron, carburizing steel for knife-blades, refractory bricks, carbon electrodes, replacements for storage batteries, the recovery of zinc from used primary cells and the alkali treatment of Clare phosphate to give a satisfactory fertilizer. A process was developed for a photo-engraving glue from fish-skins. Work was done on acetone, and processes for ethyl acetate from 80 per cent acetic acid, for agar-agar from seaweed, for an insecticide by extraction of offal tobacco, and a substitute for cutch as a preservative for fishing nets, were also worked out by the Bureau. A modified method for the determination of fat in milk was devised. Advice was given on the use of substitutes for imported wool oil, and for economy and efficiency in the use of lubricating oils.

* Emergency Scientific Research Bureau. Report. Pp. 96. (Dublin: Stationery Office, 1946.) 2*s*.

FORTHCOMING EVENTS

Tuesday, March 11

ZOOLOGICAL SOCIETY OF LONDON (at Regent's Park, London, N.W.8), at 5 p.m.—Scientific Papers.

ROYAL ANTHROPOLOGICAL INSTITUTE (at the Royal Society, Burlington House, Piccadilly, London, W.1), at 5.30 p.m.—Prof. D. Brunt, F.R.S.: "Some Problems of Climate and Man".

ILLUMINATING ENGINEERING SOCIETY (at the E.L.M.A. Lighting Service Bureau, 2 Savoy Hill, London, W.C.2), at 6 p.m.—Mr. J. Ivon Graham: "Lighting in Coal Mines".

SHEFFIELD METALLURGICAL ASSOCIATION (at 198 West Street, Sheffield), at 6.30 p.m.—Dr. Thos. B. Crow and Mr. J. F. Hinsley: "Some Anomalies and Refinements in Diamond Pyramid Hardness Testing of Heavily Cold-Rolled Strip".

INSTITUTION OF STRUCTURAL ENGINEERS, LANCASHIRE AND CHESHIRE BRANCH (at the College of Technology, Manchester), at 7 p.m.—Mr. W. L. MacIvor and Mr. S. R. Reisser: "Practical and Theoretical Approach to Correct Design for Welding".

Wednesday, March 12

MANCHESTER STATISTICAL SOCIETY (at the Reform Club, King Street, Manchester), at 5 p.m.—Mr. J. A. Petch: "The Trend of Joint Matriculation Board's Examinations".

ROYAL SOCIETY OF ARTS (at John Adam Street, Adelphi, London, W.C.2), at 5 p.m.—Mr. Reco Capey: "Economic Reconstruction, 5, Craftsmanship".

INSTITUTE OF PETROLEUM (at Manson House, 26 Portland Place, London, W.1), at 5.30 p.m.—Mr. A. Van Weelden: "Modern Developments in Geophysical Prospecting".

INSTITUTION OF ELECTRICAL ENGINEERS, TRANSMISSION SECTION (at Savoy Place, Victoria Embankment, London, W.C.2), at 5.30 p.m.—Mr. R. N. Berry: "Economics of High-Voltage Transmission by Underground Cables".

SOCIETY OF CHEMICAL INDUSTRY, MICROBIOLOGICAL PANEL OF THE FOOD GROUP (at the Chemical Society, Burlington House, Piccadilly, London, W.1), at 6.30 p.m.—Mr. B. M. Brown: "The 'Biological Stability of Beer"; Prof. B. T. P. Barker and Dr. V. L. S. Charley: "The Biological Stability of Cider, Fruit Juices and Soft Drinks".

CHEMICAL SOCIETY (joint meeting with the LOCAL SECTIONS of the ROYAL INSTITUTE OF CHEMISTRY, the SOCIETY OF CHEMICAL INDUSTRY and the BRITISH ASSOCIATION OF CHEMISTS, at the Nicholson Lecture Theatre, New Organic Chemistry Department, The University, Dansie Street, Liverpool), at 7 p.m.—Demonstration of Scientific Apparatus.

SOCIETY OF DYERS AND COLOURISTS, NORTHERN IRELAND SECTION (at the Queen's Hotel, Belfast), at 7.30 p.m.—Mr. J. G. Grundy: "The Application and Fastness Properties of Dyes on Nylon".

SOCIETY FOR VISITING SCIENTISTS (at 5 Old Burlington Street, London, W.1), at 7.30 p.m.—Discussion on "The Outlook in the History of Science" (to be opened by Prof. V. Gordon Childe, Mr. A. R. Hall, Mr. J. G. Crowther and Mr. Philip George).

Thursday, March 13

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Mr. E. W. Taylor: "The Control of Amplitude in Phase Contrast Microscopy"; Mr. J. F. P. Deller, Mr. A. D. O'Connor and Mr. A. Sorsby: "X-Ray Measurement of the Diameters of the Eye".

ILLUMINATING ENGINEERING SOCIETY, MANCHESTER CENTRE (joint meeting with the ELECTRICAL ASSOCIATION FOR WOMEN, at the College of Technology, Manchester), at 6 p.m.—Mr. T. O. Freeth: "Lighting the Home".

INSTITUTE OF WELDING, SHEFFIELD AND DISTRICT BRANCH (at the Royal Victoria Station Hotel, Sheffield), at 6.30 p.m.—Mr. H. E. Lardge: "Welding in the Development of Jet Propulsion Engines".

CHEMICAL SOCIETY (joint meeting with the LOCAL SECTION of the ROYAL INSTITUTE OF CHEMISTRY, in the Chemistry Department, The University, Manchester), at 7 p.m.—Scientific Papers.

PHARMACEUTICAL SOCIETY (at 17 Bloomsbury Square, London, W.C.1), at 7 p.m.—Mr. William C. Peck: "Recent Developments in Pharmaceutical Apparatus".

SOCIETY OF DYERS AND COLOURISTS, WEST RIDING SECTION (at the Great Northern Victoria Hotel, Bradford), at 7.15 p.m.—Dr. H. P. Standinger: "Polymer Chemistry".

CHEMICAL SOCIETY (joint meeting with the LOCAL SECTIONS of the ROYAL INSTITUTE OF CHEMISTRY and the SOCIETY OF CHEMICAL INDUSTRY, at the North British Station Hotel, Edinburgh), at 7.30 p.m.—Prof. A. C. Chibnall, F.R.S.: "The Composition and Structure of Proteins".

Friday, March 14

TEXTILE INSTITUTE (at 16 St. Mary's Parsonage, Manchester), at 1 p.m.—Mr. L. J. Clarke: "Some Recent Trends in Ribbon Manufacture".

ROYAL ASTRONOMICAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Scientific Papers.

CHEMICAL SOCIETY (at King's College, Newcastle-on-Tyne), at 5 p.m.—Dr. H. Bassett: "Some Pages from the Chemistry of Aluminium" (Bedson Club Lecture).

INSTITUTION OF MECHANICAL ENGINEERS (at Storey's Gate, St. James's Park, London, S.W.1), at 5.30 p.m.—Mr. A. J. R. Lysholm: "A Contribution to the Solution of the Gas Turbine Problem".

OIL AND COLOUR CHEMISTS' ASSOCIATION, MANCHESTER SECTION (at the Engineers' Club, Albert Square, Manchester), at 6.30 p.m.—Dr. E. H. Farmer: "The 'Isomerisation' of Oils—Thermal and Oxidative Changes Involved Therein".

INSTITUTE OF PHYSICS, MANCHESTER AND DISTRICT BRANCH (joi meeting with the INDUSTRIAL RADIOLOGY GROUP, in the New Phys Theatre, The University, Manchester), at 7 p.m.—Dr. L. H. Gra "The Physical Properties of Very High Voltage X-Rays and Electr and their Medical Interest".

CHEMICAL SOCIETY (in the Chemistry Lecture Theatre, The Unive ity, Glasgow), at 7.15 p.m.—Prof. A. C. Chibnall, F.R.S.: "T Composition and Structure of Proteins".

INSTITUTE OF METALS, SHEFFIELD SECTION (in the Mining Lect Theatre, The University, St. George's Square, Sheffield), at 7.30 p —Prof. H. W. Swift: The "Mechanism of Sheet-Metal Drawing".

Saturday, March 15

BIOCHEMICAL SOCIETY (at Guy's Hospital Medical School, Londo S.E.1), at 2.30 p.m.—Annual General Meeting, and Scientific Pape

SCHOOL NATURE STUDY UNION (at the City Literary Institu Stukeley Street, Drury Lane, London, W.C.2), at 2.30 p.m.—4 Annual Conference; at 3 p.m.—Sir Clive Forster-Cooper, F.R. "Adaptation to Environment".

INSTITUTE OF PHYSICS, ELECTRONICS GROUP (joint meeting with t MIDLAND BRANCH of the INSTITUTE OF PHYSICS, in the Univers Edmund Street, Birmingham), at 2.30 p.m.—Prof. P. B. Moon: "T Acceleration of Electrons and Ions to Energies of the Order of 10^8 e.v.

Monday, March 17

ROYAL SOCIETY OF ARTS (at John Adam Street, Adelphi, Londo W.C.2), at 5 p.m.—Dr. J. A. V. Butler: "Enzymes" (Canter Lectur 2).

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS (at t Royal Victoria Station Hotel, Sheffield), at 6.15 p.m.—Dr. J. Sincla "The Underground Mechanization of Coal Mines".

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on before the dates mentioned:

LECTURESHIP IN GEOGRAPHY—The Registrar, The Universi Reading (March 17).

LECTURER IN THE DEPARTMENT OF GEOGRAPHY—The Secretar The University, Aberdeen (March 20).

ASSISTANT LECTURER IN THE DEPARTMENT OF GEOGRAPHY—T Registrar, The University, Sheffield (March 21).

SENIOR PRINCIPAL SCIENTIFIC OFFICER in the Directorate of Instr ment Research and Development of the Ministry of Supply—T Civil Service Commission, 6 Burlington Gardens, London, W.1, quot No. 1816 (March 21).

CHIEF FUEL ENGINEER—The Director of Establishments, Minist of Fuel and Power, 7 Millbank, London, S.W.1, marked 'Chief Fu Engineer' (March 21).

TRAINING OFFICER—The Executive Officer, Kent War Agricultur Executive Committee, Mote House, Maidstone (March 22).

CHAIR OF INORGANIC AND PHYSICAL CHEMISTRY at King's Colleg Newcastle-upon-Tyne—The Registrar, University Office, 46 Nor Bailey, Durham (March 22).

SENIOR CIVIL ENGINEERING ASSISTANT—The Water Engineer, Dale Street, Liverpool (March 24).

CO-ORDINATOR OF RESEARCH AND PRINCIPAL AT THE PUNJAB AGR CULTURAL COLLEGE, LYALLPUR—The High Commissioner for Indi General Department, India House, Aldwych, London, W.C.2 (Mar 28).

PRINCIPAL OF THE SCHOOL OF PHYSIOTHERAPY AND HEAD OF TH PHYSIOTHERAPY DEPARTMENT—The House Governor, Royal Victor Infirmary, Newcastle-upon-Tyne (March 31).

PROFESSIONAL OFFICERS FOR RHODESIA METEOROLOGICAL SERVIC —The Secretary, Office of the High Commissioner for Southe Rhodesia, Rhodesia House, 429 Strand, London, W.C.2 (March 31).

TECHNICAL DEVELOPMENT OFFICER—Establishment Branch (Roo 266), Department of Agriculture for Scotland, St. Andrew's Hou Edinburgh 1 (March 31).

LECTURER (woman) IN THE DEPARTMENT OF EDUCATION (gradua in Biology, Chemistry or Physics)—The Registrar, University Colleg Hull (April 14).

LECTURER IN HELMINTHOLOGY—The Dean, London School Hygiene and Tropical Medicine, Keppel Street, Gower Street, Londo W.C.1 (April 15).

LECTURER IN PHYSIOLOGY—The Secretary, Queen's Universit Belfast (May 1).

LECTURER IN BIOCHEMISTRY for Department of Dental Surgery The Registrar, The University, Liverpool (May 15).

PROFESSORSHIP IN THE DEPARTMENT OF CHEMISTRY—The Registra Dacca University, P.O. Ramna, Dacca (East Bengal), India (May 31

DIRECTOR OF THE SOUTH AFRICAN PAINT RESEARCH ASSOCIATION South African Scientific Liaison Officer, 39 Princes Gate, Exhibitio Road, London, S.W.7.

ASSISTANT BIOCHEMIST preferably with experience of hospital bl chemistry and hæmatology—The Medical Superintendent, Dudl Road Hospital, Birmingham 18.

LECTURER IN GENETICS at Auckland University College, Ne Zealand—The Secretary, Universities Bureau of the British Empir 24 Gordon Square, London, W.C.1.

SENIOR LECTURER IN MATHEMATICS at Auckland University Colleg New Zealand—The Secretary, Universities Bureau of the Brit Empire, 24 Gordon Square, London, W.C.1.

DIRECTOR OF RESEARCH—The Physician Superintendent, Runw Hospital for Nervous and Mental Disorders, Wickford, Essex.

SENIOR TRANSMISSION ENGINEER for Hydro-Electric Scheme Ceylon—The Director of Recruitment (Colonial Service), 15 Victo Street, London, S.W.1.

SENIOR ASSISTANT PHYSICIST to the Birmingham National Radi therapy Centre—The Secretary, Birmingham United Hospital, T Queen Elizabeth Hospital, Birmingham 15.